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THE STATUS OF BROWN PELICANS AT ANACAPA ISLAND IN 1975 [1]

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Data of 1975 on productivity, chemical residues, and eggshell thickness of California brown pelicans at Anacapa Island and nearby Santa Cruz Island suggest that the colonies are recovering from DDT-related reproductive failures. The improved productivity reported for 1974 continued through 1975. However, productivity, residues of DDE, and eggshell thickness in 1975 were not significantly different from those of 1974, suggesting that the rate of improvement has begun to level off. Pelican productivity is still too low for population stability.

Chemicals other than DDE are discussed. PCBs were also found at levels of possible concern in brown pelican eggs. PCB levels probably were lower in pelican eggs in 1973–75 than in previous years (1969–72), but recent levels seem to have stabilized.

Brown pelican colonies will require continued monitoring for some years to come. We recommend that the California brown pelican be retained on the California list of endangered fauna until: 1) productivity exceeds 1.0 young per nest attempt, and 2) the numbers of breeding adults in California waters begin to increase.

INTRODUCTION

The status of brown pelicans (*Pelecanus occidentalis californicus*) in the coastal waters of California and just south into Mexico at Islas Los Coronados through 1974 was reviewed by Anderson et al. (1975) and Anderson and Anderson (1976). In 1971, there was enough concern about the brown pelican population decline in the Channel Islands area to have the subspecies placed on California's list of "endangered wildlife" (Leach 1972, 1974). Although brown pelicans historically have nested on other islands in California waters (Gress 1970), Anacapa Island (lat 34°01'N, long 119°26'W) and nearby Scorpion Rock off Santa Cruz Island (lat 34°03'N, long 119°33'W) have been the only nesting sites used in California waters since our studies were initiated. The California nesting population of brown pelicans has been monitored since 1969 by a team from the Department of Fish and Game (DFG), U.S. Fish and Wildlife Service (USFWS), U.S. National Park Service (USNPS), and University of California.

We report here on the status of pelican colonies on Anacapa and Santa Cruz Islands in 1975. Reasons for the decline of California's brown pelicans will not

[1] This study supported in part by Federal Aid in Wildlife Restoration Project W-54-R "Nongame Wildlife Investigations." Accepted for publication April 1976.

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be reviewed here (see Anderson and Anderson 1976). A significant recovery in pelican productivity (young fledged per nest attempt) began around 1972 (Anderson et al. 1975). Productivity in 1974 was significantly better than that observed from 1969 to 1973.

Owing to the extreme severity of the brown pelican problems formerly caused by DDT pollution, only DDT and metabolites were reported by Anderson et al. (1975). In this report, we will also discuss other chemical pollutants found in brown pelican eggs off Southern California.

METHODS

Colony surveys were conducted throughout the breeding season from a boat anchored below the colonies by the Department of Fish and Game and U.S. National Park Service on 30 March, 10 April, 22 April, 30 April, mid-June, 8 August, and 8 September. On most occasions, one or more of us were present on these surveys. No entries were made into the nesting area until all young were of bandable size. After that, when human presence was no longer hazardous (on 8 August and 8 September), the nesting areas were entered and more accurate productivity data were obtained. Eggshells and addled eggs were collected. We found no carcasses in 1975. Young were banded and color-marked.

Our methods of chemical analysis for organochlorine residues are cited by Anderson et al. (1975). Residue analyses reported here were conducted by the USFWS, Denver Wildlife Research Center, Denver, Colorado. Residues of organochlorine pollutants are given as ppm lipid–basis. To convert these to a rough estimate of ppm fresh-weight basis, multiply our values by 0.05.

Unfortunately, in 1975 we recovered only four intact brown pelican eggs that were suitable for chemical analysis; three of these were dried and putrified. Stickel et al. (1965) reported exaggeration of egg residues by as much as eight times in dessicated eggs. Putrefaction apparently does not decompose the organochlorines (Mulhern and Reichel 1970), although it is essential to adjust residues for losses of moisture. Incubation and possibly putrefaction apparently resulted in the loss of some egg lipids in three eggs (see Romanoff 1932) to about 0.6 of their normal value. Five to 6% lipid content is normal for fresh brown pelican eggs (D. W. Anderson unpublished). We therefore corrected residues in our 1975 sample for lipid and water loss (Stickel et al. 1973) and then converted them to a lipid-basis, assuming 5% lipids, so that they would be comparable with previous years' data. Residues of heavy metals were analyzed by atomic absorption spectrophotometry according to the methods described by I. Okuno, Denver Wildlife Research Center.

RESULTS

Productivity of Brown Pelicans

At least three periods of nesting activity were apparent during the nesting season of 1975 on Anacapa and nearby Santa Cruz. This asynchronous nesting pattern made our surveys more difficult than in previous years, but we are confident that out estimates are accurate.

Production on the separate islands was as follows in 1975: Anacapa—212 nests, 182 young produced; Santa Cruz—80 nests, 74 young produced. The two colonies combined produced 0.88 young per nest attempt. This compares with 0.73 in 1974, 0.14 in 1973, 0.22 in 1972, and 0.007 in the period 1969–71 for the

same colonies (Anderson and Anderson 1976).

Our productivity estimates for 1975 suggest a slight improvement over 1974, but this was not statistically significant as suggested by the overlap of the 95% confidence intervals (CIs) of the two estimates (Steel and Torrie 1960): 1975—CI = 0.79–1.03, 1974—CI = 0.51–1.05.

Residues in Brown Pelican Eggs

Mean DDE residues in 1975 (ppm lipid-basis) were slightly higher than in 1974 (Table 1), but not significantly so (Wilcoxon two-sample test, $P > 0.1$, Sokal and Rohlf 1969:391–394). Eggshell thickness did not differ significantly between 1974 and 1975 in either intact or broken eggs (Table 1).

TABLE 1. Pollutant Residues and Eggshell Thicknesses of Brown Pelican Eggs from Anacapa Island in 1975 Compared with Previous Years' Data from the Same General Area.

	Year			
Measurements	*1969**	*1973**	*1974**	*1975*
Chemicals (geometric $\bar{X}$, ppm)	n = 28	n = 4	n = 39	n = 4
p,p'–DDT + *p,p'*–DDD (lipid-wt.)	54	7	ND	ND
p,p'–DDE (lipid-wt.)	853	175	97	113
PCB (lipid-wt.)†	200	43‡	146	120
Hexachlorobenzene (lipid-wt.)	—	—	—	0.09
Mercury (wet-wt.)	—	0.30	—	0.10
Lead (wet-wt.)	—	0.18	—	0.14
Cadmium (wet-wt.)	—	<0.05	—	<0.05
Shell Thickness (arith. $\bar{X}$, mm)				
Intact eggs, mean ± 95% CI	0.40	0.51	0.48	0.51
	±0.02	±0.07	±0.02	±0.04
Intact eggs, sample size	12	4	59	9
Broken eggs, mean ± 95% CI	0.29	0.34	0.38	0.36
	±0.02	±0.03	±0.03	±0.06
Broken eggs, sample size	53	26	27	13

* Data on DDT and metabolites are from Anderson et al. (1975). A dash means that the residue was not determined, and ND means the chemical was tested for, but not detected. Chemicals are reported for intact eggs only.

† 1969 PCB residues are from Risebrough (1972) and were quantified on the basis of Arochlor 1254. The 1973–75 PCBs were quantified on the basis of Arochlor 1260. Therefore, these residues are not rigorously comparable. A correction factor of 2.15 (Risebrough and deLappe 1972) was applied to the data, but no statistical test was made.

‡ Without one value of 6 ppm, this mean would be 86 ppm.

Residues of PCBs (polychlorinated biphenyls) (Peakall and Lincer 1970, Dustman et al. 1971), although not associated with eggshell thinning in birds (Peakall and Peakall 1973), may be responsible for parental behavior changes observed in the Anacapa brown pelicans (i.e., reduced nest attentiveness) (Peakall and Peakall 1973, Gress 1970). Mean PCB residues (lipid-weight) were around 200 ppm in 93 intact and crushed eggs at Anacapa in 1969 (Risebrough 1972), but averaged 146 ppm in 1974 and 120 ppm in 1975 (Table 1). Although these residues were measured by different laboratories, the data suggest that PCBs may have declined since 1969, but not as dramatically as did DDT and metabolites over the same time period (Anderson et al. 1975) (Figure 1). DDE and PCB residues in eggs appear to have remained essentially unchanged in the last 2 years, but the possible discrepancies in analyses of PCBs do not allow statistical testing of the hypothesis of a decline in PCBs since 1969. Young and Szpila

(1975) have reported a recent decrease in PCBs in mussels (*Mytilus californicus*) of Southern California; as with pelicans, the decrease in PCBs was less than that in DDT compounds.

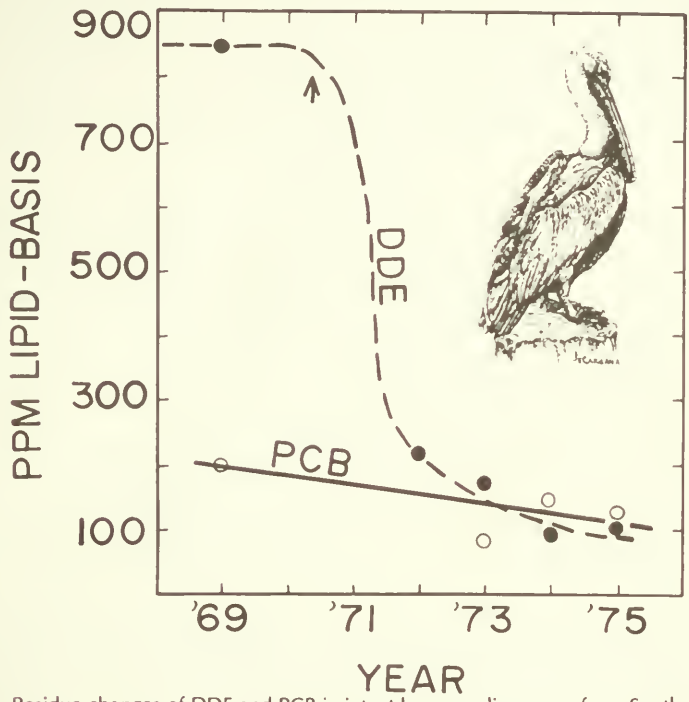

FIGURE 1. Residue changes of DDE and PCB in intact brown pelican eggs from Southern California. The arrow indicates a major drop in environmental input of DDT. According to published data, major input of DDT ceased in 1970 (Anderson et al. 1975) and by 1971 it had decreased to about 0.5% of previous levels (Jukes 1974, citing the DDT-manufacturing company president). There is some disagreement as to the actual levels of input before 1970 (Jukes 1974).

The other major organochlorine residue found in pelican eggs at Anacapa Island was dieldrin. The mean dieldrin level (lipid-basis) was 1.29 ppm in seven of the 1973–74 pelican eggs, but less than 1 ppm (the level of analytical sensitivity) in the other 36. Fourteen additional eggs of normal shell thickness, collected in 1973 in the Gulf of California (D. W. Anderson USFWS, unpublished data), contained a mean of 0.95 ppm dieldrin. No dieldrin was detected above the level of analytical sensitivity in our small sample of pelican eggs from 1975. Dieldrin levels were similarly low at Anacapa in 1969, with a mean of 0.98 ppm lipid–basis for 19 eggs in which the chemical was tested (R. W. Risebrough pers. commun.). This level was judged to be unrelated to eggshell thinning in Anacapa brown pelicans (Risebrough 1972).

We also conducted a small number of analyses for residues of mercury, lead, and cadmium (Table 1). All of the levels were low, as were those found in Anacapa eggs in 1971 (Conners et al. 1972) and in 22 eggs collected in the Gulf of California in 1973 (D. W. Anderson USFWS, unpublished data). Means were:

0.58 ppm Hg, 0.10 ppm Pb, and <0.05 ppm Cd (all residues of metals expressed on a ppm fresh-weight basis of egg contents). Sell (1975) has reported that domestic poultry retain little ingested cadmium (4% after 23 days), and that virtually none is deposited in either the egg yolk or albumin. Therefore, the low cadmium levels we report here are difficult to evaluate and probably do not truly reflect exposure. Lead and mercury, like dieldrin, appear to be unrelated to the past reproductive-eggshell problems of Anacapa's brown pelicans. Cadmium levels need to be determined from other tissues, but we do not suspect that levels in the Anacapa area are unusually high (Martin and Broenkow 1975).

DISCUSSION

Our 1975 data indicate that the improvement in brown pelican productivity reported in 1974 (Anderson et al. 1975) is continuing, but with the rate of improvement leveling off. Our data on eggshell thickness and pollutant residues support this conclusion (Table 1). The continued improvement is encouraging, but it may be that DDE levels have again "stabilized" in the brown pelicans off Southern California (Figure 1) and that a complete recovery of reproductive potential is still some years in the future.

DDE is persistent with an unusually long half-time, it accumulates at low dietary levels, and mobilizes rapidly and at realistically low laboratory doses (review by Stickel 1975). The eggshell thinning effect of DDE persists, although it lessens, at least 1 year, and likely more (W. H. Stickel pers. commun.), after experimental birds are placed on clean diets (Haegele and Hudson 1974). The situation off California might be considered as an acute problem becoming a chronic one.

Apparently, the non-DDT residues examined in brown pelican eggs are either at low levels or not changing rapidly. Some of these pollutant levels may represent additional, less acute, and less obvious ecological problems off Southern California, such as those that might be manifested by low levels of PCBs or combinations of DDE and PCB (Risebrough and Anderson 1975). These and the heavy metal residues will be difficult to evaluate ecologically and physiologically.

We estimate that current productivity is still 10–30% below what it should be to maintain long-term population stability, depending on how the data are interpreted. A "recruitment standard" has been postulated to estimate the necessary productivity for brown pelicans by Henny (1972) based on a small sample size of band recoveries for the eastern subspecies. Based on more recent field studies on productivity (D. W. Anderson and R. W. Schreiber USFWS, unpublished data, Schreiber 1975) the figure postulated by Henny (1.2 to 1.5) seems too high.

For example, the populations of brown pelicans in Florida are relatively stationary (Williams and Martin 1970, Schreiber and Schreiber 1973, Schreiber 1976). One colony on the west coast of Florida has been monitored for 7 years by R. W. Schreiber (pers. commun.); this colony has produced an average of about 1.0 young per nest (range = 0.3 to 1.7) from 1969 to 1975 (Schreiber 1975). This colony, colonies on the west coast of Florida, and colonies throughout Florida have not shown any trend of decline (Schreiber and Schreiber 1973). Only long-term studies will reveal what constitutes the average productivity or recruitment that will interact with mortality and immigration to produce popula-

tion stability or increase in the brown pelican.

Also, as Anderson et al. (1975) pointed out, different proportions of the total adult pelican population breed from year to year. Thus it becomes difficult to estimate if a population is increasing or decreasing on the basis of short-term colony census data. There is no doubt that the population of brown pelicans breeding off Southern California is currently much smaller than it was prior to 1949 (Anderson and Anderson 1976), and there is no doubt that productivity has improved since 1971. Recruitment of new breeders from the 1974–75 production probably will not be seen until recently-produced pelicans are 3–5 years old (Anderson and Anderson 1976). Only time will tell if the breeding population increases because of the improvement.

Long-term productivity above about one young per nest attempt, coupled with a sustained increase in the breeding population of brown pelicans off California, should be the minimum criteria in judging whether to remove brown pelicans from the State's list of endangered fauna. In conclusion, we recommend that the brown pelican be retained on the California list of endangered fauna, since the State's only viable pelican colonies on Anacapa and Santa Cruz are still not reproducing sufficiently for population stability (Anderson et al. 1975).

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Our studies have been coordinated by H. R. Leach (DFG), and we are grateful for his continuing support. The USNPS, Channel Islands National Monument, has provided continual aid in the field. W. H. Ehorn and F. Jacot have cooperated in our research and continually responded to our management recommendations for Anacapa Island. The USFWS, Denver Wildlife Research Center has also provided continuous support for brown pelican research on the West Coast. We are grateful to H. H. Hoover for continuing assistance. R. E. White and the laboratory at the Denver Wildlife Research Center conducted our chemical analyses. R. W. Schreiber and W. H. Stickel made valuable comments on the manuscript.

In 1976, productivity on Anacapa declined to 0.67 young per nest (n-about 400 nests). There was no pelican nesting on Santa Cruz in 1976. Visits into the Anacapa colony were too late to obtain eggshells and addled eggs, but analysis of two young found dead on the colony (A.L. Bischoff pers. commun.) indicated low organochlorine residues. The poor 1976 productivity was at least in part due to a failure as suggested by: 1) badly emaciated dead young in the colony, and 2) low numbers of adults in or near the colony on 25 July (19 compared to around 1,000 in previous years). Young were produced in 1976, but the nesting season was asynchronous and many young starved on the colony before fledging. Surveys will continue in 1977.—D.W.A.

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SUPPLEMENTAL DATA ON THE FOOD HABITS OF THE WESTERN GRAY SQUIRREL [1]

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Supplemental data from Kern, Mendocino, Sonoma, Napa, Shasta and Tehama counties substantiates the feeding habits pattern of the western gray squirrel over much of its California distribution. Hypogeous fungi, oak acorns, pine nuts and California bay fruits comprise the bulk of the food eaten by gray squirrels. The types of fungi and principal food items are eaten in a pronounced seasonal pattern.

INTRODUCTION

The purpose of this report is two-fold:

1) To add supplementary information to available data on the food habits of the western gray squirrel (*Sciurus griseus*) from Tehama, Trinity, El Dorado, Nevada, Calaveras, Amador and Humboldt counties (Stienecker and Browning 1970).
2) To document the similarity of the food habits pattern of gray squirrels throughout their statewide distribution.

The principal collection areas considered are in Mendocino and Kern counties. Supplemental collections were made in Sonoma, Napa and Shasta counties (Figure 1); an additional sample is from Tehama county.

DESCRIPTION OF THE PRINCIPAL AREAS

Mendocino Collection Area

This sample was taken on the University of California Hopland Field Station, located in the southeast corner of Mendocino County. Gray squirrels were collected below the chaparral belt at an elevation between 244 to 549 m (800 to 1,800 ft). A woodland-grass association characterizes the greater part of the collection area. The overstory consists of blue oak (*Quercus douglasii*), valley oak (*Quercus lobata*), and California buckeye (*Aesculus californica*). In the dense woodland type, located in small ravines along the streams and on the north slopes, the principal trees are live oak (*Quercus agrifolia*), California bay (Umbellularia californica), madrone (*Arbutus menziesii*) and black oak (*Quercus kelloggii*). Between 1951–1960 the average rainfall was 94 cm (37 inches) per year at the Hopland Field Station. During the period, the first freezing temperatures took place between October 6 and November 18. The last frost occurred between March 23 and May 22. The lowest temperature was —8 C (17 F), with an average of 70 days with frost each winter.

[1] This study was supported by Federal Aid in Wildlife Restoration Projects W-52-R "Wildlife Laboratory" and W-47-R "Upland Game Investigations." Accepted for publication December 1975.

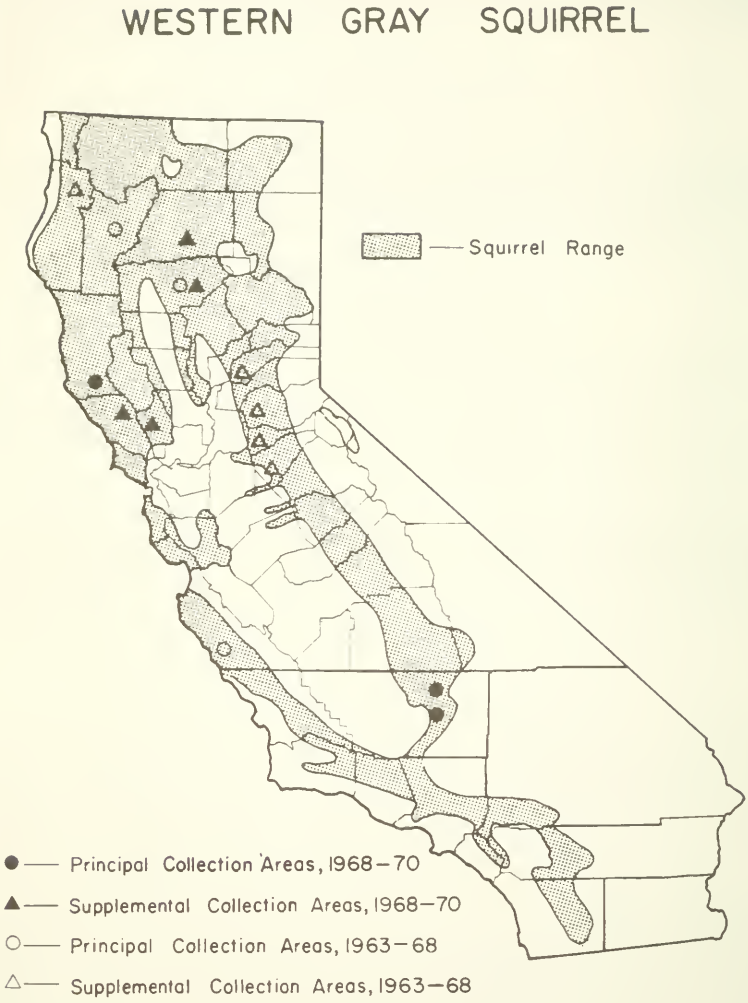

FIGURE 1. Collecting areas and range of the western gray squirrel in California.

Kern Collection Area

The Kern sample was taken in the Greenhorn Range and on Breckenridge Mountain, in the southern tip of the Sierras, approximately 35 miles east of Bakersfield. The terrain varies from rolling hills to steep canyons. At lower elevations the forest association consists of blue oak, California buckeye and digger pine (*Pinus sabiniana*). In both study areas, which are about 1,219 to 1,524 m (4,000 to 5,000 ft) in elevation, yellow pine (*Pinus ponderosa*) is the dominant tree, along with sugar pine (*Pinus lambertiana*). Incense cedar (*Calocedrus decurrens*) is common in the Greenhorn Range, but noticeably absent on Breckenridge Mountain. White fir (*Abies concolor*) is found in both areas. Black oak is common in both areas and is well distributed throughout the yellow pine association.

The highest rainfall in Kern County, ranging from 50 to 60 cm (20 to 25 inches) a year, falls on the slopes of the Greenhorn Range and Breckenridge Mountain. Most precipitation occurs in winter with snow at the higher elevations. Summer thunderstorms occur, but are not common. Freezing temperatures usually start in early October and persist as late as May, sometimes reaching below 0 F. Summer temperatures average 21 C (69 F), with extremes over 32 C (90 F) unusual. The average annual temperature is 13 C (55 F).

SAMPLES AND METHODS

A total of 207 gray squirrel stomach samples were analyzed from Kern County. The squirrels were collected by shooting from December, 1968 through December, 1970. From the University of California Hopland Field Station in Mendocino County, 68 gray squirrel stomach samples were analyzed and were collected from May, 1969 through April, 1970. Supplementary collections were made from the following counties: Sonoma (31), Napa (4), Tehama (7) and Shasta (3). The method of analysis is described in a previous paper (Stienecker and Browning 1970).

RESULTS

Food habits analyses of the Kern and Mendocino samples show that hypogeous fungi, acorns, pine nuts, California bay fruit and vegetative leaf and stem fragments were the staple food items eaten by the western gray squirrels. These five food items contributed 95% of the total items eaten by Kern County squirrels (Table 1) and 90% of the items eaten by squirrels in Mendocino County (Table 2). The 31 Sonoma County squirrels (Table 3) selected 99% of their food from the above five items. The food samples from Napa, Shasta and Tehama counties indicated a similar pattern (Table 3).

TABLE 1. Food Items Eaten by 207 Western Gray Squirrels, Kern County, December 1968–December 1970

	Jan. (10)		Feb. (10)		Mar. (14)		April (19)		May (17)		June (16)	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Fungi, Hypogeous	32.2	9	25.1	8	34.3	13	50.5	18	63.9	16	70.3	15
Oak acorns *Quercus* sp.	67.0	10	69.3	10	55.1	13	29.7	12	31.8	8	14.3	7
Pine nut fgmt. *Pinus* sp.	0.6	2	--	--	Tr.	1	--	--	1.5	3	4.4	6
Green vegetation	0.2	2	0.1	2	1.3	5	4.3	8	--	2	4.7	5
Insect and larva fgmts. (Insecta)	Tr.	1	Tr.	3	4.1	4	3.4	10	Tr.	11	Tr.	7
Fir seed *Abies* sp.	--	--	--	--	--	--	--	--	--	--	--	--
Miners' lettuce sd. and lf. *Montia* sp.	--	--	5.3	2	3.4	4	Tr.	1	1.5	1	3.1	2
Incense cedar *Calocedrus decurrens*	--	--	--	--	--	--	3.2	2	1.2	1	--	--
Manzanita fr. and sd. *Arctostaphylos* sp.	--	--	--	--	--	--	--	--	--	--	--	--
Oak catkins *Quercus* sp.	--	--	--	--	--	--	5.0	1	--	--	--	--
Unid. conifer seed	--	--	--	--	--	--	3.9	1	--	--	--	--
Unid. nut fgmts.	--	--	--	--	--	--	--	--	--	--	--	--
Unid. squirrel skin and hair (carrion)	--	--	--	--	1.8	1	--	--	--	--	--	--
Woody fgmts.	--	--	Tr.	2	Tr.	2	--	--	0.1	3	Tr.	3
Grit	--	--	--	--	--	--	--	--	Tr.	1	2.8	1
Fungi, Epigeous	--	--	--	--	--	--	Tr.	1	--	--	--	--
Unid. seed	--	--	--	--	--	--	--	--	--	--	--	--
Unid. vegetative matter	--	--	--	--	--	--	Tr.	2	--	--	0.3	1
Grass leafage (Graminеae)	--	--	--	--	--	--	Tr.	2	--	--	0.1	1
Mistletoe lf. *Phoradendron* sp.	--	--	0.2	1	--	--	--	--	--	--	--	--
Oak leafage *Quercus* sp.	--	--	--	--	--	--	Tr.	1	--	--	--	--
Dry pine needle fgmts. *Pinus* sp.	Tr.	2	--	--	Tr.	2	Tr.	1	Tr.	2	Tr.	5
Rootlet fgmts.	--	--	Tr.	1	--	--	Tr.	1	Tr.	1	--	--
Lichen fgmts.	--	--	Tr.	1	--	--	--	--	--	--	--	--
Insect egg and case (Insecta)	--	--	--	--	Tr.	1	Tr.	1	Tr.	1	--	--
Ant fgmts. (Formicidae)	--	--	--	--	--	--	--	--	Tr.	2	--	--
Selaginella fgmts. *Selaginella* sp.	--	--	--	--	--	--	--	--	--	--	Tr.	1
Fir needle fgmts. *Abies* sp.	--	--	--	--	--	--	--	--	--	--	Tr.	1
Unid. bud fgmts.	--	--	--	--	--	--	--	--	--	--	Tr.	1
Feather fgmts.	--	--	--	--	--	--	--	--	--	--	--	--
Pitch (amber, hard)	--	--	--	--	Tr.	1	--	--	--	--	--	--
Unid. animal matter	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 1. Food Items Eaten by 207 Western Gray Squirrels, Kern County, December 1968–December 1970—Continued

	July (21)		Aug. (25)		Sept. (14)		Oct. (18)		Nov. (23)		Dec. (20)		Totals (207)	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Fungi, Hypogeous	90.2	21	48.0	22	25.3	11	24.7	12	46.9	23	41.4	12	48.4	180
Oak acorns *Quercus* sp.	3.2	3	17.5	11	32.8	9	37.8	12	50.5	23	47.6	14	34.9	132
Pine nut fgmt. *Pinus* sp.	5.0	10	32.4	15	29.1	6	27.2	11	--	--	4.5	6	9.7	60
Green vegetation	1.6	4	Tr.	1	0.4	1	Tr.	1	1.3	2	1.3	4	1.3	37
Insect and larva fgmts. (Insecta)	Tr.	5	Tr.	4	7.4	6	Tr.	2	Tr.	4	--	--	1.1	57
Fir seed *Abies* sp.	--	--	--	--	4.3	1	5.5	1	--	--	--	--	0.8	2
Miners' lettuce sd. and lf. *Montia* sp.	--	--	--	--	--	--	--	--	--	--	--	--	0.8	10
Incense cedar *Calocedrus decurrens*	--	--	1.4	2	--	--	--	--	0.1	1	--	--	0.6	6
Manzanita fr. and sd. *Arctostaphylos* sp.	--	--	--	--	--	--	--	--	--	--	4.8	1	0.4	1
Oak catkins *Quercus* sp.	--	--	--	--	--	--	--	--	--	--	--	--	0.4	1
Unid. conifer seed	--	--	--	--	--	--	--	--	--	--	--	--	0.4	1
Unid. nut fgmts.	--	--	--	--	--	--	4.2	1	--	--	--	--	0.4	1
Unid. squirrel skin and hair (carrion)	--	--	--	--	--	--	--	--	--	--	--	--	0.1	1
Woody fgmts.	Tr.	2	0.1	2	0.6	5	0.3	3	0.1	1	--	--	0.1	23
Grit	--	--	Tr.	1	Tr.	1	Tr.	1	0.1	1	--	--	0.2	6
Fungi, Epigeous	--	--	0.6	1	--	--	--	--	--	--	--	--	0.1	2
Unid. seed	--	--	--	--	--	--	Tr.	1	0.7	2	--	--	0.1	3
Unid. vegetative matter	--	--	--	--	--	--	0.3	1	0.2	1	--	--	0.1	5
Grass leafage (Gramineae)	--	--	--	--	0.1	1	--	--	0.1	2	0.4	3	0.1	9
Mistletoe lf. *Phoradendron* sp.	--	--	--	--	--	--	--	--	--	--	--	--	Tr.	1
Oak leafage *Quercus* sp.	--	--	Tr.	2	--	--	--	--	Tr.	1	--	--	Tr.	4
Dry pine needle fgmts. *Pinus* sp.	Tr.	2	Tr.	1	Tr.	1	Tr.	1	--	--	--	--	Tr.	17
Rootlet fgmts.	Tr.	3	--	--	--	--	--	--	--	--	--	--	Tr.	6
Lichen fgmts.	--	--	--	--	--	--	--	--	--	--	--	--	Tr.	1
Insect egg and case (Insecta)	--	--	Tr.	1	--	--	--	--	--	--	--	--	Tr.	4
Ant fgmts. (Formicidae)	--	--	--	--	--	--	--	--	--	--	--	--	Tr.	2
Selaginella fgmts. *Selaginella* sp.	Tr.	1	--	--	--	--	--	--	--	--	--	--	Tr.	2
Fir needle fgmts. *Abies* sp.	--	--	Tr.	1	--	--	--	--	--	--	--	--	Tr.	2
Unid. bud fgmts.	--	--	--	--	--	--	--	--	--	--	--	--	Tr.	1
Feather fgmts.	--	--	Tr.	1	--	--	--	--	--	--	--	--	Tr.	1
Pitch (amber, hard)	--	--	--	--	--	--	--	--	--	--	--	--	Tr.	1
Unid. animal matter	--	--	--	--	--	--	--	--	Tr.	1	--	--	Tr.	1

TABLE 2. Food Items Eaten by 68 Gray Squirrels on the Hopland Field Station, Mendocino County, 1969–1970

	Jan. (5)		Feb. (7)		Mar. (6)		April (6)		May (6)		June (5)	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Fungi, Hypogeous	25.0	5	40.8	6	44.7	5	63.3	6	50.8	5	59.0	4
Acorn fgmts. (*Quercus* sp.)	75.0	5	52.2	6	33.8	5	34.5	6	4.7	2	7.8	3
California bay (*Umbellularia californica*)	--	--	1.1	1	--	--	--	--	--	--	20.0	1
Walnut fgmts. (*Juglans* sp.)	--	--	--	--	--	--	--	--	--	--	--	--
Insect and larva fgmts.	Tr.	2	0.1	3	16.5	5	Tr.	2	15.2	6	12.6	5
Filaree seed (*Erodium* sp.)	--	--	--	--	--	--	Tr.	1	27.5	2	--	--
Leaf buds	--	--	5.7	2	--	--	--	--	--	--	--	--
Unidentified matter	--	--	--	--	4.7	1	--	--	--	--	--	--
Green vegetation, forb grass	Tr.	2	0.1	4	Tr.	1	--	--	1.8	3	0.6	3
Pollen, anther fgmts.	--	--	--	--	0.3	3	2.2	3	--	--	--	--
Oak leafage (*Quercus* sp.)	Tr.	1	--	--	--	--	--	--	--	--	--	--
Woody stem fgmts.	--	--	--	--	Tr.	1	--	--	--	--	--	--
Selaginella fgmts. (*Selaginella* sp.)	--	--	--	--	--	--	--	--	Tr.	1	--	--
Rootlet fgmts.	--	--	--	--	--	--	--	--	--	--	--	--
Small galls	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 2. Food Items Eaten by 68 Gray Squirrels on the Hopland Field Station, Mendocino County, 1969–1970—Continued

	July (5)		Aug. (4)		Sept. (3)		Oct. (8)		Nov. (7)		Dec. (6)		Total (68)	
	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F	V%	F
Fungi, Hypogeous	82.0	5	50.0	4	14.7	2	21.9	4	46.6	7	33.5	6	44.3	59
Acorn fgmts. (*Quercus* sp.)	18.0	5	10.0	2	30.0	3	39.6	5	53.4	7	66.3	6	37.1	55
California bay (*Umbellularia californica*)	--	--	40.0	2	43.3	2	--	--	--	--	--	--	5.9	6
Walnut fgmts. (*Juglans* sp.)	--	--	--	--	--	--	37.5	3	--	--	--	--	4.4	3
Insect and larva fgmts.	Tr.	2	Tr.	3	11.7	1	Tr.	2	Tr.	3	Tr.	2	4.3	36
Filaree seed (*Erodium* sp.)	--	--	--	--	--	--	--	--	--	--	--	--	2.4	3
Leaf buds	--	--	--	--	--	--	--	--	--	--	--	--	0.6	2
Unidentified matter	--	--	--	--	--	--	--	--	--	--	--	--	0.4	1
Green vegetation, forb grass	--	--	--	--	0.3	2	1.0	2	Tr.	5	0.2	1	0.4	20
Pollen, anther fgmts.	--	--	--	--	--	--	--	--	--	--	--	--	0.2	6
Oak leafage (*Quercus* sp.)	--	--	--	--	--	--	--	--	--	--	--	--	Tr.	1
Woody stem fgmts.	--	--	--	--	--	--	--	--	--	--	--	--	Tr.	1
Selaginella fgmts. (*Selaginella* sp.)	--	--	--	--	--	--	--	--	--	--	--	--	Tr.	1
Rootlet fgmts.	Tr.	1	--	--	--	--	Tr.	1	--	--	--	--	Tr.	2
Small galls	--	--	--	--	Tr.	1	--	--	--	--	--	--	Tr.	1

TABLE 3. Food Items Eaten by 45 Western Gray Squirrels—Sonoma, Tehama, Napa and Shasta Counties, 1969

	Sonoma (31) November		Tehama (7) October		Napa (4) October		Shasta (3) November	
	V%	F	V%	F	V%	F	V%	F
California bay fruit *Umbellularia californica*	59.4	26	--	--	tr	1	--	--
Fungi Hypogeous	28.4	26	63.6	7	27.5	4	75.0	3
Acorn fgmts. *Quercus* sp.	9.3	11	28.6	3	61.2	4	--	--
Poison oak sd. *Rhus diversiloba*	--	--	--	--	7.5	1	--	--
Green vegetative matter	1.7	14	0.4	2	tr	3	--	--
Unidentified fruit and seed	--	--	--	--	--	--	25.0	1
Pine nuts *Pinus* sp.	0.8	1	--	--	3.8	1	--	--
Gall fragments	0.1	2	7.4	4	--	--	--	--
Unidentified matter	0.2	1	--	--	--	--	--	--
Fungi Epigeous	--	--	--	--	--	--	--	--
Woody and bark fragments	0.1	7	tr	1	--	--	--	--
Fir needle fragments	tr	3	--	--	--	--	--	--
Rootlet fragments	tr	2	--	--	--	--	--	--
Incense cedar leafage *Calocedrus decurrens*	--	--	tr	1	--	--	--	--
Animal matter	tr	7	tr	3	--	--	--	--

Fungi

In both principal collection areas hypogeous fungi were the most important food items eaten. In the Kern County sample the yearly average volume eaten was 48%. Fungi were eaten every month of the year, with the highest consumption in July (90%) and the lowest in February, September and October (25% each). In Mendocino County the yearly average volume of fungi consumed was 45.5%. Again July was high (82%) and September (15%) the lowest.

Several fungi of the order Turberales, or truffles, were important food items in both principal study areas, and occurred in the sample every month of the year. *Rhizopogon,* a false truffle in the Basidiomycetes group, was also important in Kern County, but did not occur in the Mendocino sample. Other Basidiomycetes fungi found on both areas were, in the order of their importance (by frequency of occurrence): *Melanogaster, Gautiera* and *Hysterangium.* This group of fungi occurred most often in the diet from April to August.

Several kinds of epigeous fungi were found in the squirrel stomachs analyzed. Puffballs (Order Lycoperdales) and gill mushrooms were utilized. On the Kern County study area, epigeous fungi appeared in the analyses each month except February, March and September and occurred less often in the Mendocino County sample.

Fungi was also the most significant food item of the squirrels in the supplementary collection areas of Shasta and Tehama counties, although second in importance in Napa and Sonoma counties. Tuberales and *Rhizopogon* again were the fungi most commonly selected. Puffballs and gill mushrooms also were eaten in Sonoma County.

Acorns

Acorn mast was second in importance and was eaten every month of the year in both study areas. In Kern County acorns made up 35% of the total annual diet of 207 gray squirrels collected between December, 1968 to December, 1970. Acorn use was highest in February (69%) and lowest in July (3%). In 1970 acorns made up over 50% of the squirrels' diet for every month except June, July and August. In June and August acorns were still over 25% of the total diet.

In Mendocino County, where oak was the predominant tree cover, yearly use

of acorns was 38% of the total diet. The highest use of acorns was in January (75%) and the lowest was in May (5%). Sample size probably accounts for the wide range in amounts eaten. For each of 8 months, acorns made up 30% of the Mendocino squirrels' diet, the spring and summer (May through August), again being the period of low acorn consumption.

In the Sonoma County sample, acorns made up 9% of the diet in November. Oak mast fragments also appeared in the smaller sample of squirrels from Napa and Tehama counties.

Pine Nuts

In Kern County, pine nuts were only 10% of the total annual diet. Pine seeds became an important item in the diet during the months of August (32%), September (29%) and October (27%), making pine nuts the third most important food item in Kern County. Pine nuts did not show up in the stomach samples from Mendocino County study area; made up less than 1% of the total food in Sonoma county and did not appear in the collections from the other three counties.

California Bay

Bay fruit appeared in the squirrel diet in Mendocino county, where it made up nearly 6% of the annual diet. Bay fruit appeared in the diet only in 4 months of the year, the highest consumption occurring in June (20%), August (40%) and September (43%). In the November collection of 35 samples from Sonoma and Napa counties, bay made up almost 60% of the total food eaten. It did not show up in the Kern County study, or in the small number of samples from Tehama and Shasta counties.

Green Vegetation

The leafage and stems of grass and forbs were eaten by gray squirrels every month of the year in Kern County, averaging 2% of the diet for the whole year; use of green feed reached a peak in June. Miners' lettuce (*Montia* sp.), leafage and seed, was eaten each month from February through June, being highest (5%) in February. Less than 1% of the total annual diet in Mendocino County was made up of green vegetation. However, green vegetative fragments which showed up 9 months of the year were the highest (1.8%) in May.

Other Foods

Animal matter was a significant food item in stomachs collected in Mendocino County. Insects and larvae appeared at least as trace items every month of the year. The highest percentages were consumed in March (16.5%), May (15%), June (13%) and September (12%). In Kern County, animal matter occurred in 11 months of the year, not appearing in December. However, there were only 3 months when animal matter was more than a trace item; March (4%), April (3%) and September (7%).

In Mendocino county walnut (*Juglans* sp.) fragments were found in the diet in October (37.5%). Filaree seed (*Erodium* sp.) was important in May (27.5%), comprising 70% and 95% in each of two stomachs collected on the Hopland Field Station.

In recent studies of the western gray squirrel on the western slopes of the Sierra Mountains (El Dorado County) gray squirrels were observed stripping

virtually every cone off a sugar pine tree over a period of 2½ weeks (Crase 1970). Black oak leaf buds have also been recorded as an important part of the gray squirrels' diet during a 4 week period in April, also in El Dorado County (Peterson 1971).

DISCUSSION

Fungi

Hypogeous fungi are staple foods of the western gray squirrel over much of its distribution. The percent of fungi utilized annually for each area is as follows: Kern (48%), Mendocino (44%), Trinity (58%), Tehama (58%) and Monterey (37%). The same is true for the supplemental collection areas—Napa-Sonoma counties (28%); the central Sierra area (50%) and Humboldt County (37%) (Stienecker and Browning 1970).

Hypogeous fungi are important foods not only for the western gray squirrel, but for other sciurids as well; such as the Douglas squirrel (*Tamiasciurus douglasii*), chipmunks (*Eutamias* sp.), golden-mantled ground squirrels (*Citellus lateralis*) and Beechey ground squirrel (*Otospermophilus*) (Tevis 1952, 1953); Kaibab (*Sciurus kaibabensis*) and Abert (*S. aberti*) squirrels (Keith 1965).

Although hypogeous fungi are the main food items of the gray squirrel throughout the Sierras and the northern and central Coastal Ranges, the kind and variety of fungi varies with the forest association where the squirrel seeks its food. In the Mendocino County study area, which is mostly oak-woodland, the Tuberales fungi are predominant with no representative of the *Rhizopogon* fungi in the diet. In the Kern County area, which is a conifer-oak association, the *Rhizopogon* fungi, which are associated with conifer litter (Smith and Zeller 1966), are predominant in the diet. Generally, however, there is greater variety of fungi in the diet of the squirrels taken from the conifer-oak association.

There is a seasonal pattern to the use of fungi throughout the western gray squirrel's distribution. Tuberales (the truffles) are utilized every month of the year in both Kern and Mendocino counties. *Rhizopogon* (false truffles) which did not occur in the diet of the Mendocino County sample, occurred each month in the diet of the Kern County squirrels; however, fungi consumption is highest through the spring and early summer. False truffles, particularly *Rhizopogon, Gautiera, Histerangium,* and *Melanogaster,* tend to be used more in the summer months and in some areas truffles more in the fall months.

Gray squirrels apparently are attracted to and consume an amazing variety of both hypogeous and epigeous fungi. Over 25 different fungi spores were isolated and identified, at least to Order. The Tuberales group showed the greatest variety (10 or more), while *Rhizopogon, Gautiera, Histerangium, Melanogaster* and *Lycoperdales* were represented by two to three kinds of spores each. Epigeous fungi were represented by species of *Agaricus, Boletus* and the puffballs.

Acorns

Oak mast is an important food, and makes up as much as a third of the total yearly diet of the western gray squirrel over much of its range. Acorn consumption also follows a strong seasonal pattern, most in the late fall and early winter and least in the summer. The Kern County results indicate that gray squirrels will respond to a good acorn crop. Percentages of acorns in the diet were notably higher in the Kern results. There were bumper acorn crops on the Kern study

areas in 1969 and 1970. Weather apparently is the key to a good mast crop and hence to the amount of acorns used by gray squirrels during a given year. Acorns are probably a "key" food for the western gray squirrel since good fall foods contribute to the condition of the animal prior to over-wintering (Stienecker and Browning 1970).

Pine Nuts

The nuts of several kinds of pines are another very significant gray squirrel food item. The quantity of pine nuts consumed by squirrels in Kern County was less than the amount eaten by the gray squirrels throughout the rest of the state, but the pattern of use remained the same. Gray squirrels cut and strip cones and use the nuts when they are in the "milk" stage. Pine nuts are found in the diet from mid-summer on into the fall.

California Bay

On several study areas (Monterey, Mendocino and Sonoma counties), bay fruit contributed heavily to the diet. Gray squirrels tend to feed on bay fruit from the fall through early spring, a similar use pattern to that of acorns.

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EFFECTS OF SALINITY ON LARVAL GROWTH IN THE CALIFORNIA KILLIFISH, *FUNDULUS PARVIPINNIS* GIRARD [1]

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California killifish, (*Fundulus parvipinnis*) larvae, incubated and hatched in salinities of 5, 14, 33, and 55‰, were reared for 10 weeks in their respective incubation salinities. Larvae and juveniles were fed live *Artemia* nauplii once daily (*ad libitum*). Length, wet weight, and dry weight of randomly sampled larvae were determined at 15-day intervals. Growth rates of the larvae were highest in 55 and lowest in 5‰ S. It is suggested that the observed differences in growth rates were related to the probable influence of salinity on food intake and conversion efficiency of the larvae.

INTRODUCTION

The California killifish, *Fundulus parvipinnis* Girard, although euryhaline (Keys 1930, Feldmeth and Wagoner 1972), is generally found in bays and lagoons along the coasts of Southern California and northern Baja California. Its occasional occurrence in completely freshwater habitats has been reported by Miller (1943) who observed that the average size of adult killifish from fresh water was smaller than that of the killifish from marine waters.

There is considerable field information (Canagaratnam 1959, Gunter 1961, Holliday 1971) and experimental evidence (Gibson and Hirst 1955, Kinne 1960, Holliday 1971, Weatherly 1972) suggesting that growth and size of euryhaline fishes is influenced by salinity. Salinity may affect growth through its influence on food intake, conversion efficiency and activity, which are important components of the bioenergetic budget of fishes (Paloheimo and Dickie 1966, Warren and Davis 1967).

There is no published information on the effects of environmental factors such as salinity on the growth of California killifish, particularly during the early stages of its life. This paper reports the effects of salinity on growth of killifish larvae raised in the laboratory and is part of a broader study of the role of salinity in the physiology and ecology of *F. parvipinnis* (Rao 1972).

MATERIAL AND METHODS

Killifish larvae were hatched in the laboratory under controlled temperature-salinity conditions. Methods of fertilization and incubation are described elsewhere (Rao 1974). Larvae were obtained from eggs fertilized in 33‰ S (salinity) and incubated in either 5, 14, 33, or 55‰ S.

Approximately 50 active, newly hatched larvae from each of the incubation salinities were transferred in two replicates to 3.5 l (1 gal) glass jars containing water of the same salinity as that of incubation. Lower salinities were prepared by adding dechlorinated tap water to natural sea water, higher salinities by

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adding synthetic sea salts. Cultures were maintained at a constant temperature of 21 ± 1 C (69.8 ± 1.8 F) and a light regime of 14 hours and 10 hours darkness throughout the experiment. The water in each jar was aerated continuously and exchanged every 3 days with fresh medium of appropriate salinity. Larvae and juveniles were fed live brine shrimp (*Artemia*) nauplii once daily (*ad libitum*) except on the day prior to weighing. The different salinities in the test jars had no observable effect on behavior of the nauplii or on their availability as food for the larvae. There were generally some nauplii left uneaten after each feeding, indicating that the larvae had fed to satiation. Unconsumed food and fecal matter were removed from the jars daily.

Total length, wet weight, and dry weight of five to eight randomly selected larvae from each jar were determined at 15-day intervals. Larvae were anesthetized in tricaine methanesulfonate (MS 222, 0.1 g/liter) and measured with a binocular microscope and ocular micrometer. During the latter stages of the experiment, the fish were measured with dial-reading calipers to the nearest 0.05 mm (1.97×10^{-3} inch). Wet weights of the fish were determined to the nearest 0.1 mg (3.53×10^{-6} oz). To obtain dry weights, anesthetized larvae were first rinsed in distilled water to remove any external salts; then they were oven-dried at 80 C (176 F) for 12 hours, and then at 105 C (221 F) until weight constancy was achieved. Initial and final measurements were taken on the 10th and 70th day after hatching, respectively. Removal and sacrifice of larval samples at 15-day intervals helped to maintain in each container a nearly constant ratio of biomass to volume of water throughout the test period.

Length-weight relations for the larvae reared in different salinities were examined to determine the possible influence of salinity on the 'condition' of the larvae (Tesch 1968).

RESULTS

Larval mortality during the test period was negligible ($<5\%$) in 14, 33, and 55‰ S; it was high ($>80\%$) in 5‰ S. Consequently, relatively small samples were available for determination of growth rates in 5‰ S and no larvae were available for sampling beyond the 40th day. Larval mortality in 5‰ S apparently was size-selective with smaller individuals succumbing earlier than larger fish. The heavy mortality was caused by the lowered resistance of killifish larvae to extremely low salinities (Rao 1975).

A preliminary covariance analysis showed that differences in the observed growth rates between replicates were not statistically significant for any test salinity ($p > 0.25$), justifying a pooling of data from replicates for further analysis.

Larval growth, in terms of increase in total length, showed a linear relationship in all salinities (Figure 1). Although differences in the age-length regression lines of different salinities were not statistically significant, a trend was evident in which lowest growth rates occurred in 5‰ S, while highest rates occurred in 55‰ S.

Increase in dry weight of larvae with age in different salinities is presented in Table 1. The relation between age and dry weight appears to be sigmoidal (Figure 2). There were no well-defined trends evident in the initial stages of growth. Later stages showed trends similar to those found in the age-length relation. Maximum growth rates occurred in 55‰ S, and the final dry weights achieved by fish grown in salinities of 14, 33, and 55‰ S showed significant differences ($p < 0.05$).

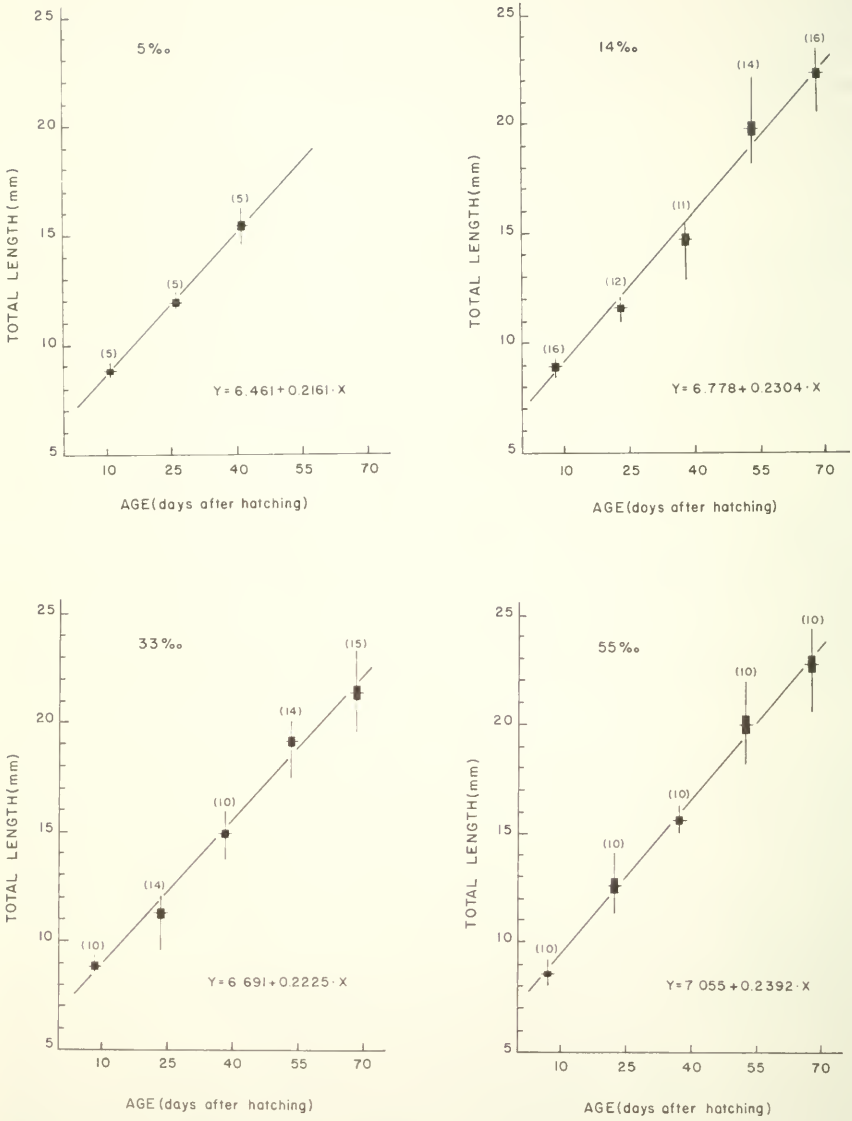

Figure 1. Age-total length relation in killifish larvae reared in different salinities. Regression lines were drawn using the given equations. At each observation point, the symbols represent range and ± one standard error. Sample size is given in parenthesis.

TABLE 1. Growth of Killifish Larvae in Different Salinities. Mean dry weight in milligrams, ($\bar{x}$), standard error (SE), and sample size (N) are shown for larvae at different ages in different salinities.

Age (days after hatching)	Salinity (‰) 5 $\bar{x}$	SE	N	14 $\bar{x}$	SE	N	33 $\bar{x}$	SE	N	55 $\bar{x}$	SE	N
10.....	1.11	0.035	9	1.16	0.037	16	1.23	0.042	10	1.07	0.047	10
25.....	3.62	0.124	5	3.05	0.221	10	2.46	0.111	14	3.58	0.321	10
40.....	7.26	0.271	5	6.50	0.353	11	6.91	0.358	10	8.19	0.248	10
55.....	–	–	–	18.19	0.673	14	16.55	0.648	14	18.68	1.214	10
70.....	–	–	–	24.19	0.846	16	21.95	0.873	15	26.87	1.509	10

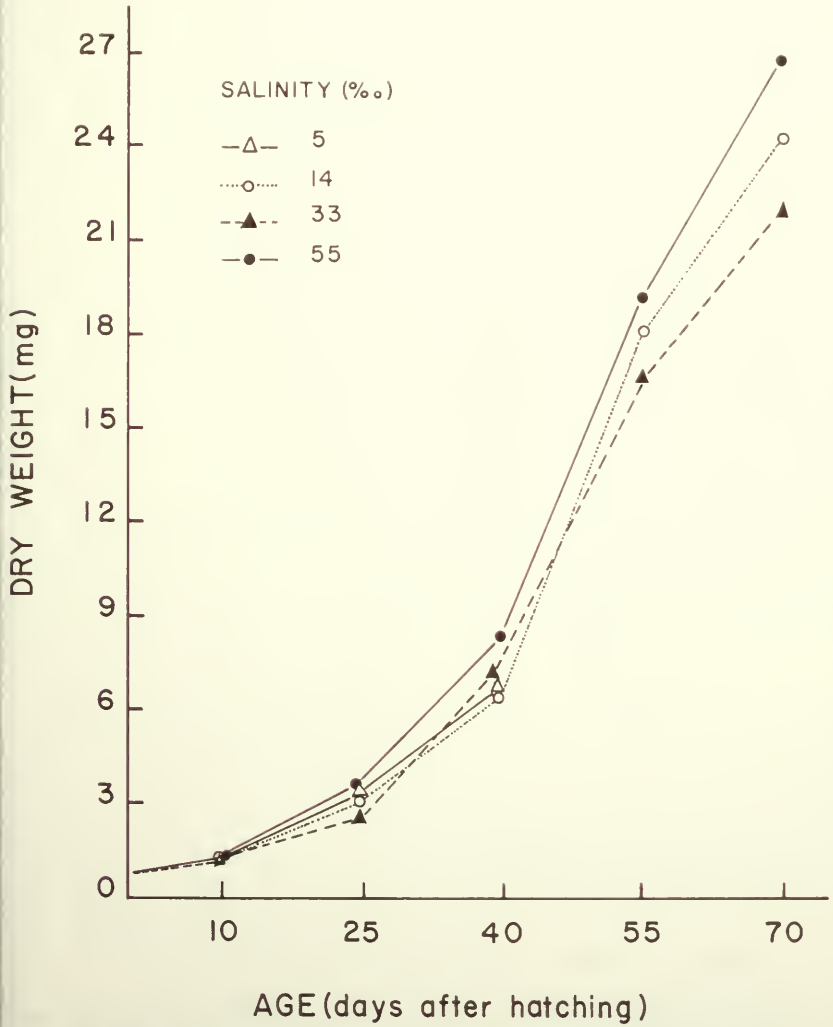

Figure 2. Age-dry weight relation in larvae reared in different salinities. Each point represents the mean of 8–15 individuals (see also Table 1).

The length (L)-weight (W) relations for larvae grown in the test salinities (Figure 3) are described by the equation:

$$\text{Log } W = \text{Log } a + b \text{ (Log } L)$$

Covariance analysis showed the Slope (b) in 5‰ S to differ significantly ($p < 0.05$) from that in salinities of 33 and 55‰. However, at the end of the experiment, there were no significant differences ($p = 0.47$) in the condition factor (dry weight/total length^3) for larvae grown in salinities 14, 33, and 55‰S.

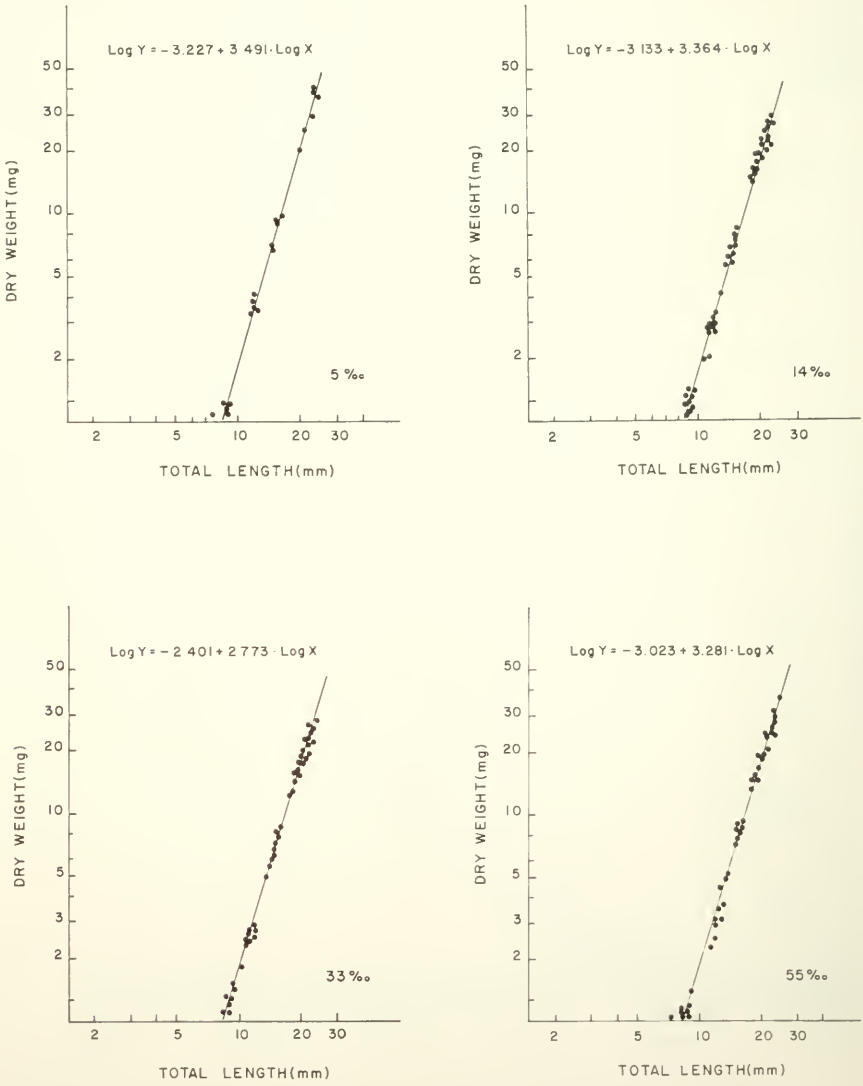

Figure 3. Total length-dry weight relation of larvae reared in test salinities. Each circle represents one individual. Regression lines were drawn using equations given in the figure.

DISCUSSION

The size-selective mortality of larvae grown in 5‰ S may have introduced bias into the growth data obtained in the present study. Such a pattern would result, at any given stage, in a higher proportion of larger individuals remaining than if mortality had been size-independent. This possible bias and the relatively small sample size in 5‰ may account for the lack of statistical significance among the different growth rates compared. A similar bias may also have influenced the data on length-weight relations of the larvae. Despite these statistical shortcomings, two interesting trends emerge from the present study: (1) The growth rates of larvae of *Fundulus parvipinnis* were lower in very low salinities (< 5‰ S), and (2) maximum growth was associated with the 55‰ S hypersaline medium. I have observed similar salinity-related trends in the growth of pre-adults of the same species (Rao 1972). Although there is considerable field and experimental evidence indicating lower growth rates of euryhaline fishes in low salinities (Canagaratnam 1959; Holliday 1971), reports of enhanced growth of fish in hypersaline water, as observed in the present study are less common. In growth studies by Kinne (1960) on the desert pupfish, *Cyprinodon macularius* and by Feltkamp and Kristensen (1970) on the molly, *Poecilia sphenops,* growth rates were lower in salinities above 35‰ S.

It has been suggested that the influence of salinity on growth may be explained in terms of the energetic cost of osmoregulation (Canagaratnam 1959). Osmoregulation, like other metabolic processes of organisms, involves energy expenditure; the relationship of this energy expenditure to the growth budget of euryhaline fishes is not well understood (Holliday 1971). The energetic cost of osmoregulation appears to be slight in certain species (Lasker and Theilacker 1962), but substantial in others (Rao 1968). Brett (1970), based on survey of pertinent literature, concludes that "except in the estuary, any advantage which the marine environment might confer on growth, through the energy-saving mechanism of reduced osmoregulation, would be small."

Oxygen consumption by *Fundulus* larvae was less in fresh water and 55‰ S, both stressful salinities, than in normal sea water (Rao 1972). Thus, it is unlikely that the bioenergetic cost of osmoregulation has contributed significantly to the growth differences observed among larvae grown in different salinities. No data are available on the activity patterns of the larvae which might be influenced by the variations in buoyancy caused by salinity.

I suggest that possible differences in food intake and food conversion efficiency were primarily responsible for the observed growth differences. Although larval food intake was not quantified in my experiments, routine observations indicated a consistently higher food intake by larvae grown in 55‰ S. The lower growth rates observed in salinities approaching fresh water are probably due to decreased food intake and low food conversion efficiency. Differences in food intake and conversion efficiency at various salinities have been demonstrated in coho salmon, *Oncorhynchus kisutch* by Otto (1971) and in desert pupfish, *Cyprinodon macularius* by Kinne (1960).

The present study suggests a salinity range (ca. 10-40 ‰ S) in which larval growth is not significantly influenced by salinity; however, salinities close to fresh water do not favor rapid growth. Miller (1943) noted differences in growth and size between individuals of marine and fresh water populations of the California killifish and suggested that habitat salinity might be the primary causative factor.

Although possible differences in the availability of food resources in marine versus fresh water habitats and genetic differences in food conversion efficiencies between marine and fresh water killifish populations can not be ignored in explaining observed size differences of killifish in Miller's study, the suggestion that habitat salinity is the major factor, is experimentally supported in the present study.

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DETECTION OF DELAYED ANNULUS FORMATION AMONG BLUEGILL, *LEPOMIS MACROCHIRUS,* POPULATIONS AT LAKE NACIMIENTO, CALIFORNIA [1]

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and C. E. VON GELDERN, JR.

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Age and growth studies of centrarchid populations are sometimes based on assumptions concerning the presence or absence of current annuli. This report examines the relationship of size and age of bluegill to time of annulus formation and considers a procedure for helping determine if current annuli are present.

INTRODUCTION

Fisheries management decisions regarding bluegill populations are often based on an analysis of age and growth characteristics. The scale method of aging is commonly used in California (La Faunce, Kimsey, and Chadwick 1964, Tharratt 1966, Miller 1971) and the validity of this technique has received a degree of general acceptance (Regier 1962, Serns and Strawn 1975).

Scale samples from angler caught bluegill at Lake Nacimiento were routinely collected and aged from 1965 through 1968 as part of an overall evaluation of an experimental introduction of threadfin shad *(Dorosoma petenense)* and white bass *(Morone chrysops)* on the Lake Nacimiento fishery. This report describes the analysis of these collections with respect to age and considers a technique for helping determine the completeness of formation of the current year's annulus among aggregations of scale samples containing a similar number of annuli. Lake Nacimiento has been described elsewhere (von Geldern 1971) and we need only note here that this 2,145-ha (5,300-acre) impoundment is located in San Luis Obispo County and contains an attractive warmwater fishery supported largely by black crappie *(Pomoxis nigromaculatus),* largemouth bass *(Micropterus salmoides),* bluegill, and white bass.

SCALE COLLECTION AND ANALYSIS

All scale samples used for these analyses were obtained from angler-caught fish in July of each study year (1965–1968) in conjunction with an extensive roving creel census (von Geldern and Tomlinson 1973). Six to 10 scales were removed from each bluegill at a point near the tip of the left pectoral fin (Proffitt 1950) and placed in individual coin envelopes marked with length of fish (FL) to the nearest 2.5 mm (0.1 inch). Scale impressions were made on cellulose acetate strips of 1.0-mm (0.04-inch) thickness with a Model B Carver Laboratory Press and examined with the aid of an Eberbach scale projector providing a magnification of 42×. A total of 1,012 usable scale samples was collected over

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the study period. Yearly sample sizes ranged from a high of 303 in 1967 to a low of 182 in 1968 (Table 1).

TABLE 1. Number of Annuli Present on Bluegill Scales from Lake Nacimiento, 1965–1968.

	Number of bluegill sampled				
Annuli present	*1965*	*1966*	*1967*	*1968*	*Totals*
I	36	18	11	0	65
II	169	251	240	60	720
III	24	26	51	109	210
IV	0	3	0	12	15
V	0	0	1	1	2
Totals	229	298	303	182	1,012

Scale samples for each study year were first segregated according to number of annuli present following criteria for annuli recognition developed by Regier (1962). Yearly collections were dominated by scales with two annuli from 1965–1967 while scales with three annuli were most prevalent in 1968.

Inherent in the sampling design was the assumption that the current year's annulus would be present on bluegill scales collected in July. This assumption was based in part on generalizations set forth by Regier (1962) indicating that time of annulus formation among normally growing bluegill populations is roughly a function of latitude and ranges from late April at 38°N to late June at 46°N. Lake Nacimiento is located at lat 35°40'N in the extremely warm Salinas Valley and was known to contain an abundant (and assumed normally growing) bluegill population which provided attractive angling. These considerations formed the basis for our initial judgment that July sampling would provide bluegill scales with recognizable annuli for the current year.

Preliminary inspection of cohorts of scales containing a similar number of annuli in a given year revealed broad variation with respect to placement of the outermost annulus. On some scales, the outer annulus was marginal or nearly so while others showed an outer annulus at a far more central location (Figure 1). Such variations in annuli placement reflect extreme growth variability among cohort members if outer annuli are assumed to have been laid down in the current year. These observations caused us to re-examine our initial premise that the current year's annulus would invariably be present on bluegill scales sampled in July.

A regularly recorded characteristic of bluegill populations is the pronounced tendency of young specimens to form annuli and resume spring growth earlier than their older counterparts (Bennett, Thompson, and Parr 1940, Lane 1954, Gerking 1966). This phenomenon has been noted for other species (Hodgson 1925, Hile 1941, Stroud 1948) and often applies not only to absolute chronological age but also to size within an age cohort; i.e., small fish form annuli earlier than larger ones of the same age (Frey 1942, Smith 1956, Bailey 1964, Gerking 1966). While this feature of spring growth resumption does not appear universal among all fish species of all ages in all types of environments (McFadden 1959, Rothschild 1963), no evidence to the contrary regarding bluegill populations has been recorded.

The tendency of young bluegill to form annuli early in the growing season is coupled with a relatively rapid rate of linear growth (Gerking 1966). Clearly, the ratio of yearly incremental growth to total growth experience (as recorded on

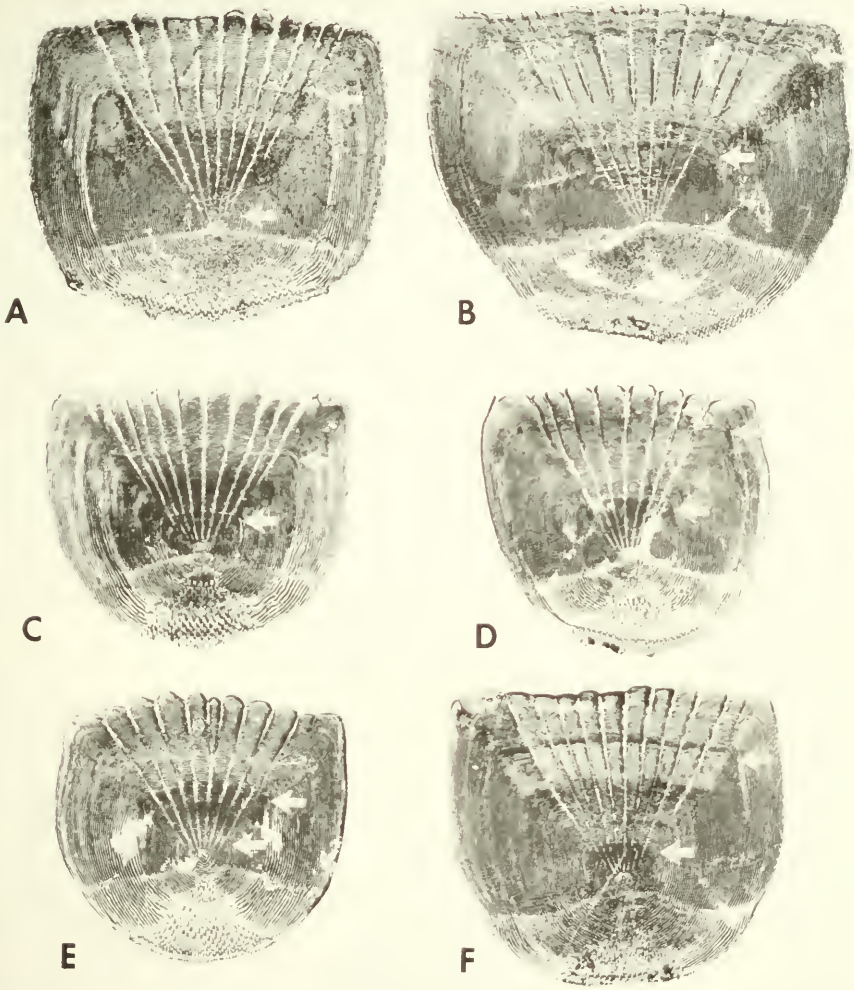

FIGURE 1. Photographs of bluegill scales showing variation in the placement of outer annuli. Scale A is from a 14.5-cm specimen collected in 1965 with an outer annulus at a central location as compared with scale B from a 20.0-cm bluegill obtained in the same year. Scales C (12.4 cm) and D (13.0 cm) were collected in 1966 and scales E (13.0 cm) and F (14.7 cm) were obtained in 1968. Arrows depict annuli.

scales) must be greatest among younger specimens of mixed age groups and/or smaller individuals of a given age cohort. By inference, it follows that such ratios must be negatively correlated with fish length among aggregations of scales with current annuli for a given year.

These observations formed the rationale for a "test" designed to help determine the completeness of annulus formation among groups of scales with a similar number of annuli. The ratio (Y/X), where

Y = the distance along the primary radius of the projected scale image from the outermost annulus to the anterior scale margin and

X = the distance from the center of the focus to the anterior scale margin,

was calculated for each bluegill sampled and plotted against fish length. Graphic plots were constructed for all groups of scales with the same number of annuli for each study year and critically examined with respect to the assumed inverse relationship between ratio (Y/X) and fish length.

Examples of Complete Annulus Formation

Graphic ratio (Y/X) and fish length relationships for bluegill scales with one and two annuli collected in 1966 are used to illustrate a case where formation of the current year's annulus was judged complete (Figure 2). The inverse relationship between (Y/X) values and fish length is clearly evident and applies not only to age but also to length within an age cohort. Among Age I specimens, fish less than the mean length of 8.9 cm (3.5 inches) had an average (Y/X) ratio of 0.58 which while those longer than the mean had an average (Y/X) value of 0.48. Age II specimens, which totally dominated the 1966 scale collection, exhibited a similar relationship; mean (Y/X) ratios for various length groupings ranged from a high of 0.38 for specimens less than 11.4 cm (4.5 inches) to a low of 0.09 for those individuals over 16.5 cm (6.5 inches) (Figure 2).

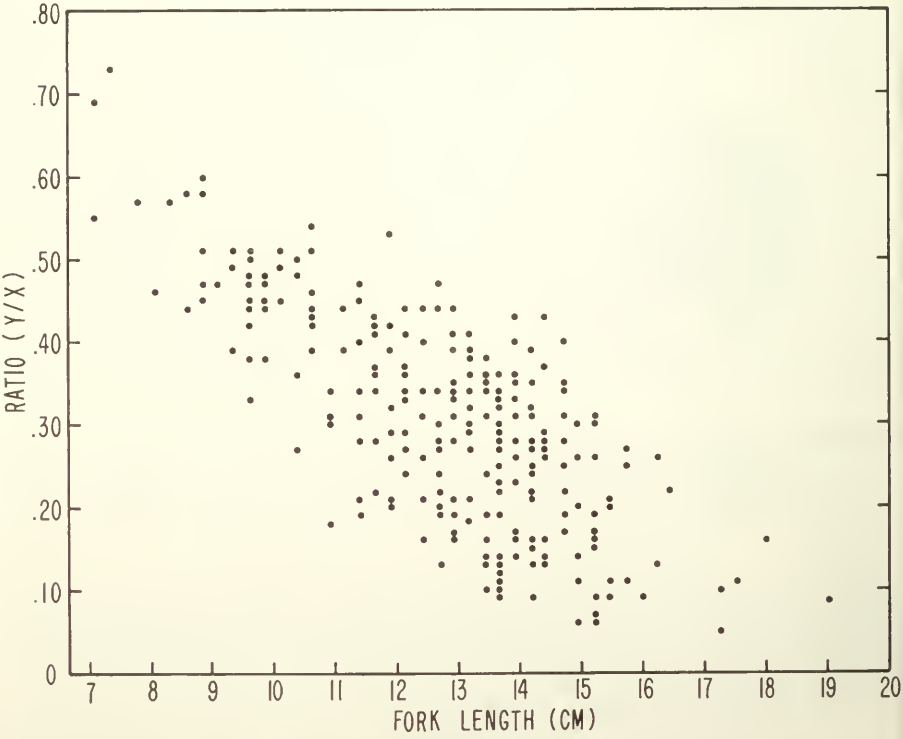

FIGURE 2. Relationship of ratio of distance from outer annulus to anterior scale margin to distance from focus to margin (Y/X) to fish length of Age I and II Lake Nacimiento bluegills in 1966.

All yearly scale samples showing a single annulus also exhibited a pronounced inverse relationship between (Y/X) values and fish length; annulus formation for this age group was, accordingly, judged complete (Appendices 1 and 2). That segment of the 1967 scale collection with two annuli showed a similar relationship (Appendix 2) and this group was also judged to have completed annulus formation for the current year.

In November 1972, a small collection of scales from angler caught bluegill was obtained at Lake Nacimiento for the purpose of comparing (Y/X) ratios and fish length relationships at (or near) the end of the growing season with those observed in July. This sampling effort was based on the premise that completed annulus formation for the current year could be assumed with near certainty for bluegill collected during the fall months and that a graphic expression of (Y/X)

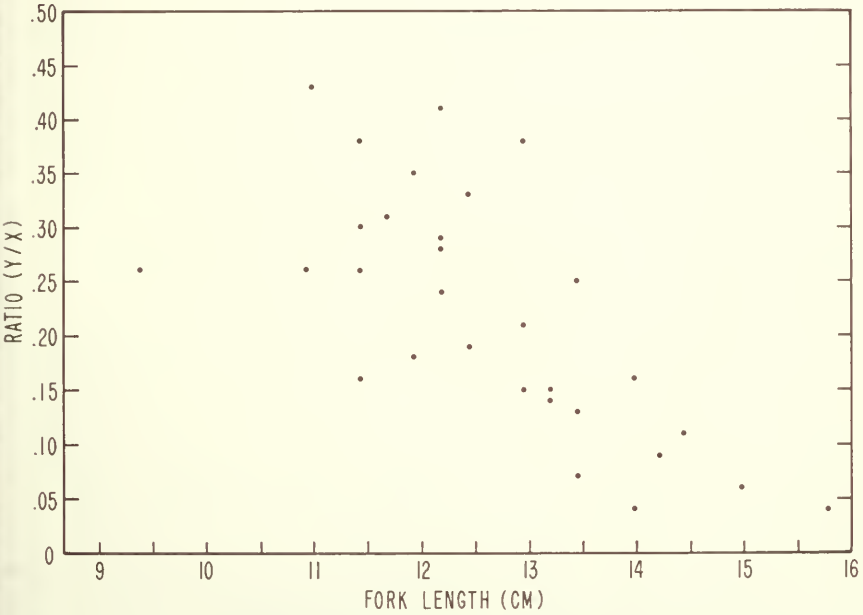

FIGURE 3. Relationship of ratio of distance from outer annulus to anterior margin to distance from focus to margin (Y/X) to fish length of bluegill collected at Lake Nacimiento in November 1972.

ratio and fish length relationships would serve as a useful check against our interpretation of similar materials constructed from July sampling. While sample sizes were small due to a scarcity of bluegill anglers in November, the inverse relationship between incremental growth and fish length was clearly evident (Figure 3). This observation served to reinforce our initial judgement concerning the appearance of such graphic relationships in situations where the current year's annulus is completely formed.

Examples of Incomplete Annulus Formation

Based on a graphic analysis of ratio (Y/X) and fish length relationships, certain segments of the Lake Nacimiento scale collection showed clear evidence of

incomplete annulus formation. Scales with two annuli collected in 1968, for example, produced an array of data points characterized by two nearly discrete groupings (Figure 4). One group had a mean ratio (Y/X) of 0.23 and a mean length 14.0 cm (5.5 inches) while the other had comparable values of 0.53 and 15.5 cm (6.1 inches). It is clear to us that the group of larger individuals were Age III specimens which had not laid down the current year's annulus and that (Y/X) values for this cohort reflect growth achieved during the previous year.

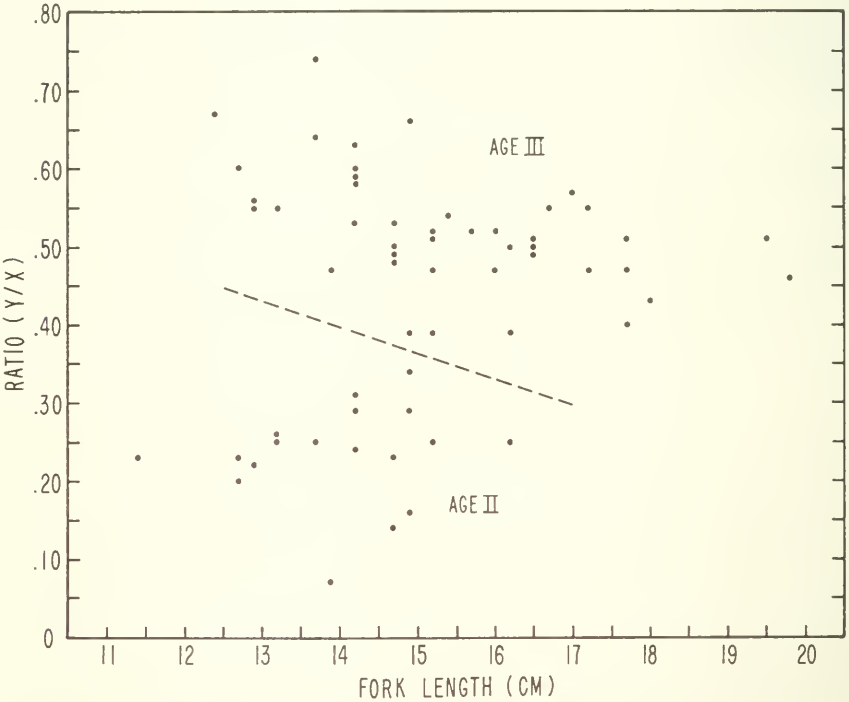

FIGURE 4. Relationship of ratio of distance from outer annulus to anterior margin to distance from focus to margin (Y/X) to fish length of bluegill with two annuli collected at Lake Nacimiento in 1968. Dashed line separates two age groups.

A second example of incomplete annulus formation was detected when graphic ratio (Y/X) and fish length relationships were plotted for bluegill scales with three annuli collected in 1967. Two aggregations of data points, separated by a clear path connecting coordinates (13.3, 0.35) and (18.0, 0.20) (Figure 5) appear to represent two age groups. One group, judged to have completed annulus formation in 1967, had a mean ratio (Y/X) of 0.21 and a mean length of 15.5 cm (6.1 inches). The second group, believed to represent Age IV specimens which had not formed current annuli, had a mean (Y/X) value of 0.35 and a mean length of 16.3 cm (6.4 inches) (Figure 5).

Other segments of the Lake Nacimiento scale collection also showed evidence of incomplete annulus formation although the separation of data points into definitive age groups involved a degree of uncertainty. Scales with two annuli collected in 1965 represent a case where a portion of the collection

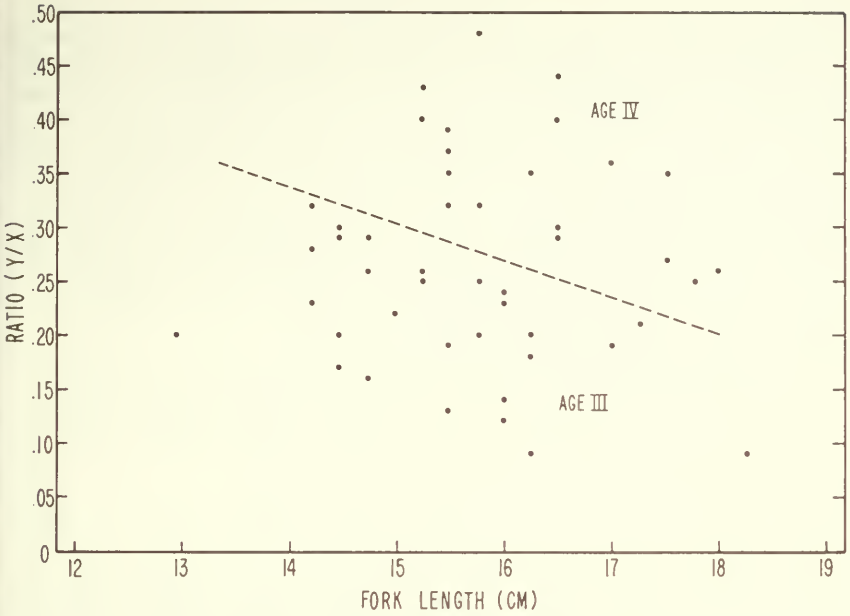

FIGURE 5. Relationship of ratio of distance from outer annulus to anterior margin to distance from focus to margin (Y/X) to fish length of bluegill with three annuli collected at Lake Nacimiento in 1967. Dashed line separates two age groups.

proved extremely difficult to age (Figure 6). The path clear of data points extending roughly from coordinates (14.0, 0.45) to (16.8, 0.20) is believed to separate Age II and Age III specimens. In the absence of a more definitive technique, an extension of this line toward the abscissa was used to further delineate the two age cohorts. We regard this procedure as arbitrary, however, and cannot rigorously defend our judgments concerning the age of bluegill depicted by data points near the extended line. Despite these misgivings, we note that such uncertainties involve only a minor fraction of the 1965 bluegill scale collection with two annuli (Figure 6). Specimens judged Age II had a mean ratio (Y/X) of 0.22 and a mean length of 15.2 cm (6.0 inches), while those judged Age III had comparable values of 0.25 and 17.3 cm (6.8 inches).

Bluegill scales with three annuli collected in 1968 produced an array of data points with certain basic similarities to that constructed from the 1965 collection with two annuli (Appendix 3, Figure 6). A path free of data points extended through a portion of the array which required an arbitrary extension in order to age the entire sample. Despite this difficulty, serious uncertainties involved only a very small percentage of the 1968 collection. Other segments of the Lake Nacimiento scale collection, comprised primarily of older individuals, were difficult to age because of small sample sizes. Nonetheless, the technique herein described was applied to these groups and we believe they were more accurately aged as a result (Appendices 1 and 2).

DISCUSSION

The age structure of segments of the Lake Nacimiento bluegill scale collection, as determined by these procedures, differed considerably from initial judgments based solely on the number of annuli present. Scales with two annuli in 1965, for example, comprised over 70% of the entire collection for that year (Table 1) although less than 50% were judged Age II (Table 2). Similarly, over 50% of the 1968 collection with two annuli were judged Age III and over 40% of the 1967 collection with three annuli were considered Age IV. In general, older age groups were more significantly affected by the application of this technique than younger cohorts; the entire Lake Nacimiento collection produced only 17 samples with four or more annuli although 85 individuals were assigned to age groups IV and V (Tables 1 and 2).

TABLE 2. Age Structure of Bluegill Sampled at Lake Nacimiento, 1965–1968.

Age	*Number of bluegill sampled*				
	1965	*1966*	*1967*	*1968*	*Totals*
I	36	18	11	0	65
II	110	251	240	18	619
III	79	19	30	115	243
IV	4	10*	21	40	75
V	0	0	1†	9‡	10
Totals	229	298	303	182	1,012

* Specimens from this cohort with four annuli (three individuals) may be Age V.
† A specimen with five annuli which may be Age VI.
‡ A single member of this cohort with five annuli may be Age VI.

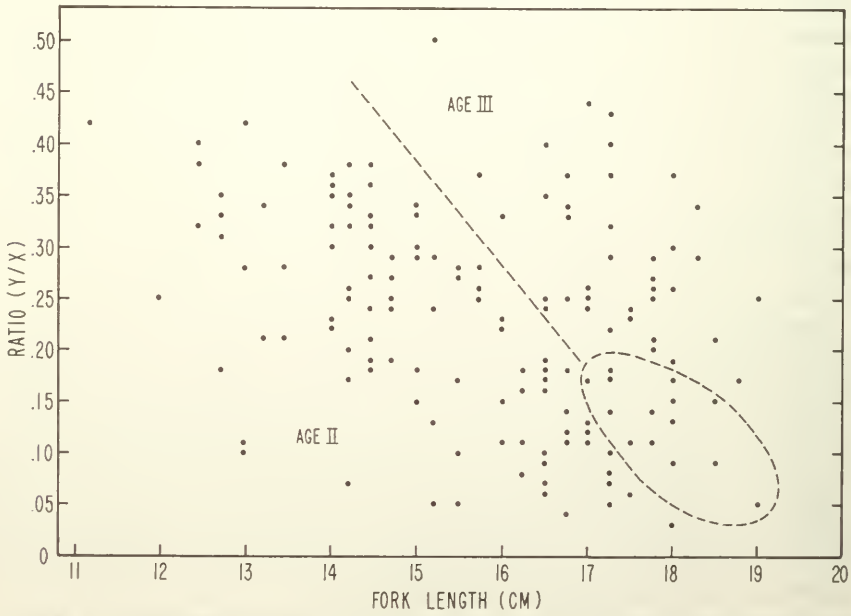

FIGURE 6. Relationship of ratio of distance from outer annulus to anterior scale margin to distance from focus to margin (Y/X) to fish length of bluegill with two annuli collected in 1965. Dashed line separates two age groups and data points within dashed circle represent bluegill judged most difficult to assign to the proper age group.

Results of this study are in general agreement with the literature regarding the time of annulus formation of bluegill of various sizes and ages. Younger age groups invariably formed annuli early in the growing season and there was a pronounced tendency for smaller members of a given age cohort to show a relatively high ratio of annual incremental growth to total growth experience. The test of Frey (1942), designed to compare sizes of carp *(Cyprinus carpio)* of a given age with and without current annuli, was applied to the present scale collection with results similar to those obtained by Gerking (1966) for bluegill; that segment of an age cohort which had formed current annuli were always of shorter mean length than their counterparts which had not (Table 3).

TABLE 3. Mean Length of Bluegill of the Same Age Cohort With and Without Current Annuli.

Collection year	Age	Mean length (cm)	
		With current annuli*	Without current annuli*
1965	III	16.9 (20)	17.5 (59)
1968	III	14.5 (73)	15.5 (42)
1968	IV	15.3 (5)	16.8 (36)

* Number in parenthesis indicates sample size.

Gerking (1966) analyzed the growth cycle and potential of bluegill populations from a number of small lakes in Indiana. In one instance, he regarded the presence of an unbroken, although highly variable, series of measurements of the number of circuli between outer annuli and the scale margin (or distance from annuli to margin) as evidence that an aggregation of bluegill scale samples belonged to the same age class. This procedure (the generation of a length frequency of (Y) alone) appears more likely than (Y/X) to detect discontinuity when plotted against a single axis since (Y) is less influenced by fish length than (Y/X). In the present case, discontinuity of data points is readily discernible only when (Y/X) is plotted against fish length because of the angular nature of paths clear of data points which separate age groups (Figures 5 and 6). In general, we favor the use of (Y/X) rather than (Y) alone because it more fully allows an interpretation of fish age based on observed relationships of size and age to annulus formation.

We believe that difficulties associated with the aging of bluegill populations will be minimized if scale collections are made as late in the growing season as possible. It is clear that generalizations relating bluegill annulus formation to latitude should not be made and this view receives a measure of support in the literature. Age III and IV bluegill from Clearwater Lake, Missouri, for example, did not complete annulus formation until September (Lane 1954). Similarly, annulus formation was not completed by early July at Lake Bastrop, Texas (Serns and Strawn 1975), even though the population was growing at a rate somewhat above the national average. At any given latitude, differences in the time of annulus formation can sometimes result in the incorrect aging of fish with marginal annuli. Such annuli should not routinely be regarded as new or current since they may represent an entire season's growth (Hansen 1937, Frey 1942) (Figure 3).

Effects of fish age on the time of annulus formation among other centrarchid species appears generally similar to that recorded for bluegill. A tendency for

young fish to form annuli early in the growing season has been observed for largemouth bass (Olmstead 1974, Webb and Reeves 1975), smallmouth bass *(Micropterus dolomieui)* (Stroud 1948), spotted bass *(Micropterus punctulatus)* (Webb and Reeves 1975), rock bass *(Ambloplites rupestris)* (Hile 1941), white crappie *(Pomoxis annularis)* (Hansen 1937, 1951, Hall, Jenkins, and Finnell 1954, Morgan 1954), and black crappie (Johnson 1945, Stroud 1948). The consistency of this observation suggests the possibility that the techniques herein described for bluegill may have utility for other warmwater species as well.

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APPENDIX 1. Ratio (Y/X) and length of bluegill with one and three annuli collected in 1965 and bluegill with three and four annuli collected in 1966.

1965 (One annulus present)

Ratio	*FL (cm)*	*Ratio*	*FL (cm)*	*Ratio*	*FL (cm)*
0.59	8.9	0.48	9.1	0.45	9.4
0.49	9.7	0.27	10.0	0.50	10.2
0.51	10.4	0.43	10.7	0.47	10.7
0.37	11.0	0.38	11.0	0.53	11.0
0.41	11.2	0.48	11.2	0.37	12.0
0.31	12.2	0.40	12.2	0.28	12.7
0.38	12.7	0.44	12.7	0.45	12.7
0.49	12.7	0.26	13.0	0.43	13.0
0.45	13.0	0.49	13.0	0.31	13.5
0.38	13.5	0.39	13.5	0.41	13.5
0.37	13.7	0.41	13.7	0.38	14.0
0.40	14.0	0.31	14.7	0.51	15.7

1965 (Three annuli present)

0.13	14.5	0.09	14.7	0.04	16.3
0.06	16.5	0.08	16.5	0.08	16.5
0.10	16.5	0.05	16.8	0.05	16.8
0.07	16.8	0.13	16.8	0.08	17.0
0.04	17.3	0.05	17.5	0.07	17.5
0.18*	17.5	0.04	17.8	0.04	17.8
0.06	17.8	0.05	18.0	0.04	18.3
0.07*	18.5	0.09*	18.8	0.13*	19.6

1966 (Three annuli present)

0.13	13.5	0.06	14.0	0.09	14.0
0.06	14.5	0.08	14.7	0.06	15.2
0.16	15.2	0.05	15.5	0.15	15.7
0.04	16.0	0.04	16.0	0.11	16.0
0.05	16.3	0.05	16.5	0.06	16.5
0.06	16.8	0.07	17.0	0.04	17.3
0.05	17.3	0.04*	18.3	0.05*	18.5
0.05*	18.5	0.06*	18.8	0.09*	18.8
0.04*	19.6	0.10*	20.1		

1966 (Four annuli present)

0.05+ 18.5	0.04+ 19.0	0.04+ 19.6

* Specimens judged not to have formed current annuli.
+ Basis for judging presence or absence of current annuli obscured by small sample size.

APPENDIX 2. Ratio (Y/X) and length of bluegill with one and two annuli collected in 1967.

1967 (One annulus present)

Ratio	*FL (cm)*	*Ratio*	*FL (cm)*	*Ratio*	*FL (cm)*
0.71	9.7	0.74	9.7	0.79	9.7
0.72	9.9	0.69	10.2	0.73	10.4
0.66	10.7	0.70	10.9	0.68	11.2
0.64	11.2	0.65	11.7		

1967 (Two annuli present)

0.58 ..... 10.4	0.46 ..... 10.7	0.55 ..... 10.7
0.63 ..... 10.7	0.50 ..... 10.9	0.61 ..... 10.9
0.67 ..... 10.9	0.69 ..... 10.9	0.70 ..... 10.9
0.59 ..... 11.2	0.62 ..... 11.2	0.67 ..... 11.2
0.52 ..... 11.4	0.53 ..... 11.4	0.55 ..... 11.4
0.57 ..... 11.4	0.59 ..... 11.4	0.59 ..... 11.4
0.61 ..... 11.4	0.62 ..... 11.4	0.64 ..... 11.4
0.66 ..... 11.4	0.46 ..... 11.7	0.48 ..... 11.7
0.55 ..... 11.7	0.56 ..... 11.7	0.60 ..... 11.7
0.62 ..... 11.7	0.63 ..... 11.7	0.65 ..... 11.7
0.49 ..... 11.9	0.52 ..... 11.9	0.54 ..... 11.9
0.56 ..... 11.9	0.58 ..... 11.9	0.61 ..... 11.9
0.64 ..... 11.9	0.47 ..... 12.2	0.50 ..... 12.2
0.50 ..... 12.2	0.53 ..... 12.2	0.57 ..... 12.2
0.57 ..... 12.2	0.60 ..... 12.2	0.60 ..... 12.2
0.46 ..... 12.4	0.47 ..... 12.4	0.49 ..... 12.4
0.60 ..... 12.4	0.60 ..... 12.4	0.61 ..... 12.4
0.63 ..... 12.4	0.42 ..... 12.7	0.44 ..... 12.7
0.46 ..... 12.7	0.47 ..... 12.7	0.49 ..... 12.7
0.50 ..... 12.7	0.50 ..... 12.7	0.50 ..... 12.7
0.54 ..... 12.7	0.51 ..... 12.7	0.54 ..... 12.7
0.59 ..... 12.7	0.55 ..... 12.7	0.59 ..... 12.7
0.63 ..... 12.7	0.61 ..... 12.7	0.63 ..... 12.7
0.47 ..... 13.0	0.64 ..... 12.7	0.22 ..... 13.0
0.49 ..... 13.0	0.48 ..... 13.0	0.48 ..... 13.0
0.50 ..... 13.0	0.49 ..... 13.0	0.49 ..... 13.0
0.53 ..... 13.0	0.50 ..... 13.0	0.53 ..... 13.0
0.57 ..... 13.0	0.56 ..... 13.0	0.56 ..... 13.0
0.61 ..... 13.0	0.60 ..... 13.0	0.61 ..... 13.0
0.40 ..... 13.2	0.24 ..... 13.2	0.30 ..... 13.2
	0.43 ..... 13.2	0.47 ..... 13.2

1967 (Two annuli present—continued)

0.50 ..... 13.2	0.52 ..... 13.2	0.54 ..... 13.2
0.54 ..... 13.2	0.56 ..... 13.2	0.30 ..... 13.5
0.31 ..... 13.5	0.31 ..... 13.5	0.44 ..... 13.5
0.45 ..... 13.5	0.47 ..... 13.5	0.50 ..... 13.5
0.50 ..... 13.5	0.51 ..... 13.5	0.52 ..... 13.5
0.59 ..... 13.5	0.59 ..... 13.5	0.62 ..... 13.5
0.29 ..... 13.7	0.29 ..... 13.7	0.45 ..... 13.7
0.46 ..... 13.7	0.46 ..... 13.7	0.48 ..... 13.7
0.49 ..... 13.7	0.51 ..... 13.7	0.51 ..... 13.7
0.51 ..... 13.7	0.51 ..... 13.7	0.52 ..... 13.7
0.53 ..... 13.7	0.54 ..... 13.7	0.34 ..... 14.0
0.35 ..... 14.0	0.36 ..... 14.0	0.37 ..... 14.0
0.39 ..... 14.0	0.41 ..... 14.0	0.45 ..... 14.0
0.50 ..... 14.0	0.51 ..... 14.0	0.51 ..... 14.0
0.52 ..... 14.0	0.27 ..... 14.2	0.43 ..... 14.2
0.43 ..... 14.2	0.43 ..... 14.2	0.47 ..... 14.2
0.48 ..... 14.2	0.48 ..... 14.2	0.51 ..... 14.2
0.55 ..... 14.2	0.58 ..... 14.2	0.60 ..... 14.2
0.60 ..... 14.2	0.31 ..... 14.5	0.35 ..... 14.5
0.40 ..... 14.5	0.46 ..... 14.5	0.48 ..... 14.5
0.50 ..... 14.5	0.51 ..... 14.5	0.54 ..... 14.5
0.56 ..... 14.5	0.33 ..... 14.7	0.33 ..... 14.7
0.34 ..... 14.7	0.38 ..... 14.7	0.39 ..... 14.7
0.40 ..... 14.7	0.42 ..... 14.7	0.44 ..... 14.7
0.46 ..... 14.7	0.46 ..... 14.7	0.49 ..... 14.7
0.50 ..... 14.7	0.50 ..... 14.7	0.50 ..... 14.7
0.51 ..... 14.7	0.27 ..... 15.0	0.34 ..... 15.0
0.37 ..... 15.0	0.38 ..... 15.0	0.39 ..... 15.0
0.42 ..... 15.0	0.43 ..... 15.0	0.45 ..... 15.0
0.46 ..... 15.0	0.47 ..... 15.0	0.49 ..... 15.0
0.49 ..... 15.0	0.50 ..... 15.0	0.52 ..... 15.0
0.54 ..... 15.0	0.34 ..... 15.2	0.35 ..... 15.2
0.36 ..... 15.2	0.38 ..... 15.2	0.38 ..... 15.2
0.39 ..... 15.2	0.44 ..... 15.2	0.47 ..... 15.2
0.49 ..... 15.2	0.49 ..... 15.2	0.32 ..... 15.5
0.34 ..... 15.5	0.37 ..... 15.5	0.40 ..... 15.5
0.41 ..... 15.5	0.42 ..... 15.5	0.43 ..... 15.5
0.43 ..... 15.5	0.43 ..... 15.5	0.47 ..... 15.5
0.51 ..... 15.5	0.34 ..... 15.8	0.36 ..... 15.8
0.39 ..... 15.8	0.39 ..... 15.8	0.39 ..... 15.8
0.39 ..... 15.8	0.39 ..... 15.8	0.40 ..... 15.8
0.40 ..... 15.8	0.42 ..... 15.8	0.43 ..... 15.8
0.44 ..... 15.8	0.46 ..... 15.8	0.46 ..... 15.8
0.56 ..... 13.2	0.57 ..... 13.2	0.64 ..... 13.2
0.47 ..... 15.8	0.48 ..... 15.8	0.48 ..... 15.8
0.28 ..... 16.0	0.34 ..... 16.0	0.36 ..... 16.0
0.37 ..... 16.0	0.39 ..... 16.0	0.42 ..... 16.0
0.43 ..... 16.0	0.45 ..... 16.0	0.33 ..... 16.3
0.41 ..... 16.3	0.37 ..... 16.5	0.41 ..... 16.5
0.27 ..... 16.8		

APPENDIX 3. Ratio (Y/X) and length of bluegill with three, four, and five annuli collected in 1968.

1968 (Three annuli present)

Ratio	*FL (cm)*	*Ratio*	*FL (cm)*	*Ratio*	*FL (cm)*
0.05	10.2	0.16	12.2	0.05	12.4
0.05	12.4	0.06	12.4	0.08	12.4
0.19	12.4	0.10	12.7	0.14	12.7
0.28	12.7	0.07	13.0	0.04	13.2
0.08	13.2	0.18	13.5	0.07	13.7
0.07	13.7	0.08	13.7	0.10	13.7
0.10	13.7	0.11	13.7	0.15	13.7
0.07	14.0	0.08	14.0	0.10	14.0
0.15	14.0	0.16	14.0	0.18	14.0
0.08	14.2	0.15	14.2	0.09	14.5
0.13	14.5	0.17	14.5	0.45*	14.5
0.03	14.7	0.04	14.7	0.04	14.7
0.04	14.7	0.04	14.7	0.09	14.7
0.09	14.7	0.09	14.7	0.09	14.7
0.11	14.7	0.15	14.7	0.04	15.0
0.04	15.0	0.07	15.0	0.09	15.0
0.11	15.0	0.13	15.0	0.13	15.0
0.06	15.2	0.08	15.2	0.09	15.2
0.09	15.2	0.13	15.2	0.20*	15.2
0.21*	15.2	0.26*	15.2	0.33*	15.2
0.43*	15.2	0.03	15.5	0.04	15.5
0.05	15.5	0.06	15.5	0.08	15.5
0.09	15.5	0.09	15.5	0.10	15.5
0.17*	15.5	0.07	15.7	0.08	15.7
0.09	15.7	0.15*	15.7	0.31*	15.7
0.32*	15.7	0.33*	15.7	0.04	16.0
0.05	16.0	0.20*	16.0	0.25*	16.0
0.03	16.3	0.06	16.3	0.06	16.3
0.08*	16.3	0.26*	16.3	0.34*	16.3
0.35*	16.3	0.04	16.5	0.10*	16.5
0.30*	16.5	0.04	16.8	0.32*	16.8
0.05*	17.0	0.10*	17.0	0.04*	17.3
0.10*	17.3	0.14*	17.3	0.15*	17.3
0.04*	17.8*	0.26*	17.8	0.18*	18.0
0.28*	18.0	0.05*	18.5	0.07*	18.5
0.46*	18.5	0.08*	18.8	0.06*	19.1
0.42*	19.1				

1968 (Four annuli present)

0.08	12.7	0.35	15.2	0.08	16.0
0.05	16.3	0.05	16.5	0.11*	17.6
0.14*	17.6	0.15*	17.8	0.06*	18.0
0.09*	18.3	0.04*	18.8	0.05*	19.1

1968 (Five annuli present)

0.07+	15.2

* Specimens judged not to have formed current annuli.
\+ Basis for judging presence or absence of current annuli obscured by small sample size.

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STOMACH CONTENTS OF NORTHERN CALIFORNIA DUNGENESS CRABS, *CANCER MAGISTER* [1]

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A total of 208 Dungeness crab, *cancer magister,* stomachs was examined from Humboldt Bay and ocean waters west of Eureka, California. The stomachs contained 40 different identifiable food items; clams, fish, isopods, and amphipods were the most frequently observed animals. Major differences in stomach contents were evident when crab stomachs from different depths were analyzed.

Northern California crab stomach contents agreed quite closely with those studied from British Columbia waters.

INTRODUCTION

A study of stomach contents of Dungeness crabs captured in the Humboldt Bay area from November 1966 through September 1969 was made to determine the types of food utilized and the relationship between stomach contents and depth of capture.

METHODS

Crabs were collected by trawling. In Humboldt Bay a 6.1-m (20-ft) skiff was used to tow a 4.9-m (16-ft) head-rope trawl with 28.7-mm (1⅛ inch) stretch mesh and 12.7-mm (½-inch) stretch mesh liner in the cod-end. Outside Humboldt Bay, both the skiff and the 30-m (100-ft) research vessel, *N.B. Scofield,* towing a 12.5-m (41-ft) head-rope Gulf shrimp trawl (28.7-mm stretch mesh) were used for collecting in the ocean. Stomachs were removed from crabs and preserved in 70% isopropyl alcohol. Data recorded for each crab included carapace width, sex, and location and depth of capture. Stomach contents were examined with a dissecting microscope. Most of the organisms found in the stomachs were not identifiable to species, due to the crushing action of the mandibles and the gastric mill. This action also precluded analysis by volumetric means. Some animals were identified by distinctive body structures, e.g., fish otoliths (Figure 1), hinges from bivalve shells, pieces of carapace and legs from crustaceans, polychaete setae, and cephalopod beaks. Whole amphipods and isopods were sent to appropriate authorities for identification. Common and scientific names are listed for convenient reference (Table 1).

[1] Accepted for publication March 1976.

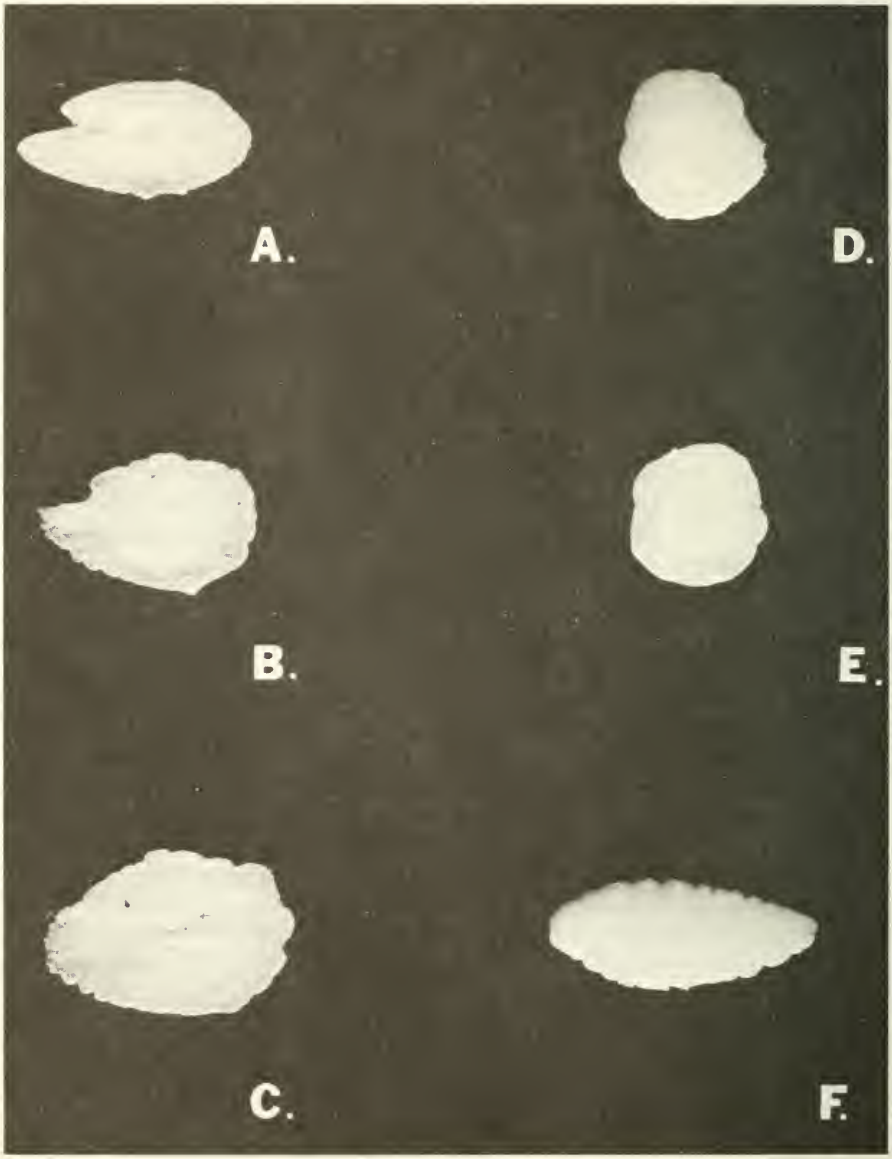

FIGURE 1. Otioliths (sagittae) found in Dungeness crab stomachs. A, Northern anchovy, *Engraulis mordax,* (right); B, Whitebait smelt, *Allosmerus elongatus,* (right); C, Night smelt, *Spirinchus starksi,* (right); D, Pacific sanddab, *Citharichthys sordidus,* (left); E, Speckled sanddab, *C. stigmaeus,* (right); F, Pacific tomcod, *Microgadus proximus,* (right). *Photograph by Jack Schott.*

TABLE 1. List of Common and Scientific Names of Organisms Used as Food by Dungeness Crabs.

Common Name	*Scientific Name*
Hydroids	Hydrozoa
Polychaete worm	Polychaeta
Brittle star	Ophiuroidae
Sand dollar	Echinoidea
Dove snail	*Mitrella tuberosa*
Moon snail	*Polinices* sp.
Nassa mud snail	*Nassarius* sp.
Snail	Gastropoda
Basket cockle	*Clinocardium nuttalli*
Clams	Pelecypoda
File yoldia	*Yoldia limatula*
Lyonsia clam	*Lyonsia* sp.
Macoma clam	*Macoma* sp.
Mussel	*Mytilus* sp.
Nut clam	*Nuculana* sp.
Razor clam	*Siliqua patula*
Cephalopods	Cephalopoda
Amphipods	Amphipoda
Bay shrimp	*Crangon* sp.
Crab	Brachyura
Crustaceans	Crustacea
Cumacean	*Diastylopsis dawsoni*
Cumaceans	Cumacea
Decapods	Decapoda
Euphausid	Euphausiacea
Isopods	Isopoda
Dungeness crab	*Cancer magister*
Shrimp	Natantia
Fish	Pisces
Night smelt	*Spirinchus starksi*
Northern anchovy	*Engraulis mordax*
Pacific sandab	*Citharichthys sordidus*
Pacific tomcod	*Microgadus proximus*
Smelt	Osmeridae
Speckled sandab	*Citharichthys stigmaeus*
Whitebait smelt	*Allosmerus elongatus*
Eelgrass	*Zostera marina*

RESULTS

A total of 208 stomachs was examined; 39 were from crabs collected in Humboldt Bay and the remainder were from crabs taken from the ocean between Table Bluff and the mouth of the Mad River. Only 26 stomachs were empty.

The stomachs contained 40 different identifiable food items (Table 2) representing six animal phyla and one plant species. Eleven animals were identifiable to species and eight to genus. Identified species included dove snail, razor clam, file yoldia, basket cockle, Dungeness crab, night smelt, whitebait smelt, northern anchovy, Pacific sanddab, speckled sanddab and Pacific tomcod. The animal phyla represented were Coelenterata (hydroids), Annelida (polychaete worms), Mollusca (snails, clams, cephalopods), Arthropoda (cumaceans, isopods, amphipods, decapods), Echinodermata (sand dollars, brittle stars), and Chordata (fishes). Plant material consisted of eelgrass fragments. The five most frequently observed categories were: unidentified clams—34.6%; unidentified fish—24.0%; isopods—17.3%; amphipods—16.3%; and razor clams—11.5%. It is interesting to note that isopods were the most frequently encountered animals in stomachs collected during November and December 1966, but those collected from approximately the same location in August and September 1969, did not contain one identifiable isopod.

TABLE 2. Frequency of Occurrence of 40 Food Items in Northern California Dungeness Crab Stomachs, August 1966 to September 1969.

Food Item	Nov.–Dec. 1966		Aug. 1967		Aug.–Sept. 1969		Combined	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Hydroids	–	–	–	–	2	2.0	2	1.0
Polychaete worms	5	7.0	1	2.6	4	4.1	10	4.8
Snails	1	1.4	–	–	3	3.1	4	2.0
Dove snail	7	9.8	–	–	–	–	7	3.4
Nassa mud snail	3	4.2	–	–	1	1.0	4	2.0
Moon snail	–	–	1	2.6	–	–	1	0.5
Clams	24	33.8	13	33.3	35	35.7	72	34.6
Razor clam	12	16.9	–	–	12	12.2	24	11.5
Nut clam	3	4.2	–	–	–	–	3	1.4
File yoldia	–	–	–	–	1	1.0	1	0.5
Macoma clam	–	–	8	20.5	–	–	8	3.8
Basket cockle	–	–	4	10.2	2	2.0	6	2.9
Lyonsia clam	–	–	1	2.6	–	–	1	0.5
Mussel	–	–	3	7.7	–	–	3	1.4
Cephalopods	–	–	–	–	2	2.0	2	1.0
Crustaceans	–	–	–	–	8	8.2	8	3.8
Cumaceans	–	–	4	10.2	13	13.3	17	8.2
Cumacean	–	–	–	–	2	2.0	2	1.0
Isopods*	35	49.3	1	2.6	–	–	36	17.3
Amphipods +	8	11.3	9	23.1	17	17.3	34	16.3
Euphausid	–	–	–	–	4	4.1	4	2.0
Decapods	10	14.1	–	–	–	–	10	4.8
Shrimp	–	–	2	5.1	2	2.0	4	2.0
Bay shrimp	–	–	–	–	5	5.1	5	2.4
Crab	–	–	5	12.8	12	12.2	17	8.2
Dungeness crab	–	–	–	–	7	7.1	7	3.4
Sand dollar	2	2.8	–	–	1	1.0	3	1.4
Brittle star	–	–	–	–	17	17.3	17	8.2
Fish	6	8.4	33	84.6	11	11.2	50	24.0
Night smelt	–	–	–	–	1	1.0	1	0.5

Whitebait smelt	–	–	–	–	12	12.2	12	5.8
Smelt	–	–	–	–	16	16.3	16	7.7
Northern anchovy	–	–	–	–	1	1.0	1	0.5
Pacific sanddab	–	–	–	–	1	1.0	1	0.5
Speckled sanddab	–	–	1	2.6	1	1.0	2	1.0
Pacific tomcod	2	2.8	–	–	3	3.1	5	2.4
Eel grass	–	–	6	15.4	8	8.2	14	6.7
Sand	–	–	2	5.1	21	21.4	23	11.0
Unidentified material	21	29.6	–	–	18	18.4	39	18.7
Number of Stomachs Examined	71		39		98		208	
Number Empty	17		1		8		26	
Crab size range (mm carapace width)	97–200		67–105		90–178			

* one genus identified—*Synidotea* (Jarl-Ove Stranberg, pers. commun.)
+ two genera identified—*Parcohoxus* and *Ampelisca* (J. L. Barnard, pers. commun.)

TABLE 3. Frequency of Occurrence of Eight Major Faunal Groups in Northern California Dungeness Crab Stomachs, August 1966 to September 1969.

Fauna Group	*Nov.–Dec. 1966 (ocean)*		*August 1967 (bay)*		*Aug.–Sept. 1969 (ocean)*		*Combined*	
	frequency	*percent*	*frequency*	*percent*	*frequency*	*percent*	*frequency*	*percent*
Hydroids	0	0.0	0	0.0	2	2.0	2	1.0
Polychaetes	5	7.0	1	2.6	4	4.1	10	4.8
Snails	8	11.3	0	0.0	4	4.1	12	5.8
Clams	36	50.7	24	61.5	51	52.0	111	53.4
Cephalopods	0	0.0	0	0.0	2	2.0	2	1.0
Crustaceans	37	52.1	15	38.5	53	54.1	105	50.5
Echinoderms	2	2.8	0	0.0	17	17.3	19	9.1
Fish	7	9.8	34	87.2	35	35.7	76	36.5

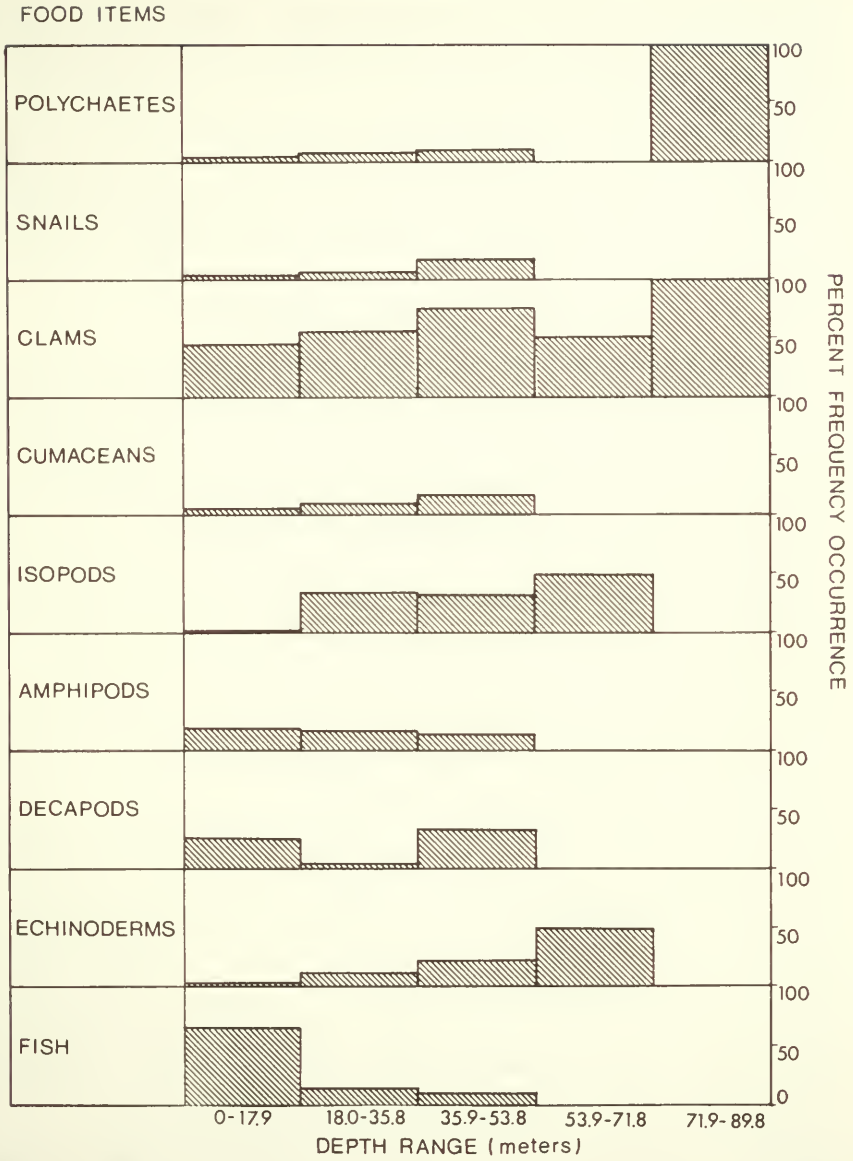

FIGURE 2. Frequency of occurrence of nine food categories found in Dungeness crab stomachs collected from 0 to 89 m (49 fm) grouped by 18-m (10-fm) intervals.

Generally, clams, crustaceans, and fish were the three most important food items. Fishes were dominant in stomachs examined from Humboldt Bay in 1967. Crustaceans were the most frequently occurring animals in crab stomachs collected outside the bay in 1969 (Table 3).

Major differences in stomach contents were noted when comparisons of crabs caught from 18-m (10-fm) depth intervals were made (Figure 2). Contents from the 208 stomachs were placed into nine categories. The percent frequency of occurrence of amphipods and fish decreased with increasing depth, while polychaetes, snails, clams, cumaceans, isopods and echinoderms increased in frequency.

DISCUSSION

Butler (1954) examined 170 Dungeness crab stomachs collected in the vicinity of the Queen Charlotte Islands, British Columbia. He found crustaceans were the most frequently occurring food item, followed by clams, with only four stomachs containing fish remains. In his study there was a large difference between stomach contents of small and large crabs, but very little difference in stomach contents between sexes. In Butler's study small crabs (less than 100 mm) fed mostly on small crustaceans, the larger crabs (166 mm or larger) fed primarily on clams. Clams, followed by crustaceans, were the most frequently observed animals in intermediate-size crabs (101 to 165 mm) from British Columbia. Conversely, fish, crustaceans, and clams were of almost equal importance in northern California for intermediate-size crabs (101 to 150 mm). In my study fish were the most frequently observed organism in stomachs from small crabs (less than 100 mm) while clams were more frequently observed in large crabs (151 mm and larger). Finally, he observed a high frequency of Dungeness crab remains in stomachs collected during August.

The results of the two studies are similar in that both showed clams as important food items. Differences in the studies occurred in order of importance of major food organisms. In the California study, clams and crustaceans were the most frequently observed faunal categories, respectively; in the stomachs examined from Canada, crustaceans were the most frequently observed food followed by clams. Northern California crabs were also cannibalistic, having eaten very small incoming year-class crabs in late summer (Table 2), but to a lesser degree than Queen Charlotte Island crabs. The most obvious difference in the two studies is the almost total absence of fish in Queen Charlotte Island crab stomachs, and the high incidence of fish remains in northern California crab stomachs. Most of the fish remains came from crabs collected in less than 18 m (10 fm). The otoliths examined were primarily from fish less than 1-year old. Evidently crabs are capable of capturing juvenile fishes and possibly some adults that come within their range. It may be that the shallow waters tend to be more murky making it easy for crabs to capture fish.

Butler describes crab feeding behavior as probing in the substrate with claws until contact with a food object is made, then the claws close. The large number of infaunal (animals living in the substrate) organisms that were found in both studies substantiates this observed feeding behavior. I have observed crabs "digging" basket cockles in southeastern Alaskan waters; some of the crabs had excavated cavities approximately 0.3-m (1-ft) deep. A few of the crabs in these

excavations were clutching large cockles. The high frequency of sand in northern California crab stomachs probably resulted from this type of feeding (Table 2).

From my study in northern California and from Butler's work, it appears that Dungeness crabs are opportunistic feeders, utilizing organisms encountered on or near the surface of the substrate (fish, crustaceans, brittle stars) as well as buried clams and worms.

Because of the wide diversity of food items found in the stomachs, it does not seem likely that presence or absence of a particular benthic animal would be a major limiting factor on the present crab population.

ACKNOWLEDGMENTS

This study could not have been completed without the assistance and suggestions of the following: John Span and Paul Dinnel assisted in collection of the crabs and preliminary sorting of stomach contents; John Fitch identified otoliths; Jarl-Ove Stranberg identified isopods; J. L. Barnard identified amphipods; and the figure was illustrated by Cathy Short. My sincere thanks to all for their contributions.

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REACTIONS OF FISH RED BLOOD CELLS WITH MUCUS AND SERA FROM OTHER FISH(ES) [1]

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The possibility was tested that an incompatibility among fishes may be based on skin mucus from some individuals reacting, probably immunologically, with red blood cells from other individuals.

A preliminary study demonstrated that mucus from mullet, *Mugil cephalus,* clumped red cells from one of several tilapia, *Tilapia mossambica.* However, tilapia mucus had little, if any, effect on the tilapia red cells. A more extensive study was then carried out with red cells from the milkfish, *Chanos chanos,* tested against mucus and sera from the same milkfish, snapper, *Lutianus fulvus,* and tilapia. No reactions of cells occurred in milkfish mucus or any serum, but there were moderate to strong reactions in the mucus of many snapper and a few tilapia.

Research in progress is attempting to determine the frequency of mucus and red cell incompatibility reactions among and between other species; if there is an *in vivo* correlation of these *in vitro* findings, especially what the disease consequences (and, therefore, the significance to aquaculture) might be; and the value of a possible preventive measure.

INTRODUCTION

Individuals of the same or different fish species are known to produce incompatibility reactions among members of the same group or between groups. These are frequently behavioral, e.g., when individuals contest for dominance over territory, but can also be chemical. In the latter case, chemicals may manifest themselves by preventing spawning or hatching of eggs, slowing growth, increasing mortality, or decreasing heart rate (Francis, et al. 1974).

The possibility of an immunologic type of chemical incompatibility existing among fishes does not seem to have been explored. However, such an incompatibility is suggested by relatively recent reports of fish skin mucus containing antibodies with some degree of specificity against mammalian red blood cells (Di Conza 1970; Bradshaw, et al. 1971), or containing high molecular weight immunoglobulins (Di Conza and Halliday 1971; Fletcher and White 1973), including IgM (Bradshaw, et al. 1971), which commonly react immunologically with red cells. Absorption of such antibodies into the blood of susceptible fishes could theoretically cause a clumping of red cells with subsequent hemolysis and anemia. This might be expected in only a certain percentage of individuals in any one tank; and might explain the familiar observation, at least in some cases, of only certain fishes "going downhill." Such debilitated animals might also be expected to be the first to develop disease which, once established, may then spread to other members of the tank population.

My research explored the possibility that skin mucus from certain individual fishes may react with red cells from other individuals, both of the same and of different species. In a preliminary study, mucus from the mullet, *Mugil cephalus,*

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and tilapia, *Tilapia mossambica,* was tested against red cells from the latter species. These species were used because of availability, and because of the chance observation of an anemia in one tilapia that possibly was the result of an incompatibility reaction of its red cells with mucus from other tilapia or mullet that had been in the same tank. In a second study, both mucus and sera from the milkfish, *Chanos chanos,* snapper, *Lutianus fulvus,* and another sample of tilapia were tested against red cells from the milkfish. This study extends the number of species tested for mucus and red cell reactions, and might indicate if there is any relationship between mucus and serum effects on red cells.

MATERIALS AND METHODS

Obtaining Mucus

Mucus from a mullet selected at random was collected by first lightly blotting the fish with a paper towel to remove excess water, followed by gently rubbing it from head to tail with the fingers. This action seemed to stimulate secretion of mucus, as well as to cause it to collect in front of the moving hand. Mucus from the milkfish, snapper, and tilapia was collected easily by letting the animals thrash a few minutes in a net out of the water. The mucus accumulated as a froth over the body, from which it was readily removed by the rubbing action just described. Each fish was placed back in the net several times so that it could continue to thrash and additional amounts of mucus could be collected. The mucus was placed directly into a vial and centrifuged at 2,200 $\times$ g for 10 min at 25 C (77 F). The clear supernatant was then stored frozen until ready for testing with red cells.

Obtaining Sera and Red Cells

Milkfish, snapper, and tilapia were bled by first blotting, as explained for the mullet, to remove excess water, and then severing the caudal peduncle with a knife. The blood was allowed to flow alternately into two vials, one empty and the other containing EDTA (anticoagulant).

Blood collected in the first vial was allowed to clot in the refrigerator. After 1 to 2 hr, the clot was freed from the edges of the vial by "rimming" with an applicator stick. The next day, the clear serum was withdrawn by pipette from the clot and either used immediately or stored frozen until ready for testing against red cells.

The anticoagulated blood in the second vial was diluted with saline (0.85 g % NaCl) solution so that the final volume of fluid to settled (uncentrifuged) cells was approximately 5:1. This cellular suspension was then used, either the same day or after a maximum of one night's storage in the refrigerator, in the tests with mucus and sera.

Testing Mucus and Sera against Red Cells

One drop of mucus or serum was mixed with one drop of red cell suspension on a microscope slide. Controls were one drop of saline solution mixed with one drop of the suspension. These mixtures were allowed to incubate under a Petri dish cover at 25 C (77 F) for up to 3 or 4 minutes before being read, as described below. Strong reactions, however, were noticeable within a few seconds.

Test I

Mucus from one mullet and five tilapia were individually tested against red cells from each tilapia. Controls were saline solution and tilapia red cells.

Test II

Mucus and sera from the same 10 milkfish, four snapper, and six tilapia were individually tested against red cells from each of the milkfish. Controls were saline solution and milkfish red cells.

Key to Rating of Reactions

A scale of 0 to 4+ was followed:

0 = No reaction; cells dispersed.
1+ = Slight clumping, but most cells dispersed.
2+ = Slightly larger clumps; interspersed fine strands.
3+ = Several large clumps; increased number and thickness of strands; loose network; slightly hazy background.
4+ = Usually one, sometimes a few, large clumps in tight network; well-developed strands in reticular formation; clear background.

RESULTS

The first test (Table 1) demonstrated a moderately strong (2+) reaction of at least one tilapia's red cells in mullet mucus. The other reactions were equivocal (0–1+), and one was clearly negative (0). Mixing of tilapia mucus and red cells also gave negative results, except for one case where the results appeared equivocal.

TABLE 1. Reactions of Tilapia Red Cells with Mucus (Test I)

Red cells Tilapia	*Mucus*				*Saline (control)*
	Mullet	*Tilapia*			
		1–3	*4*	*5*	
1	2+	0	0	0	0
2	0	0	0	0	0
3	0–1+	0	0–1+	0	0
4	0–1+	0	0	0	0
5	0–1+	0	0	0	0

Note: 0, no reaction, cells dispersed; 1+, slight clumping, but most cells dispersed; 2+, slightly larger clumps, interspersed fine strands.

In the second test (Table 2), none of the milkfish mucus or any sera reacted with the red cells of this species. However, the mucus from three of the four snapper and from two of the six tilapia reacted moderately to strongly with red cells from a number of milkfish. Only one fish, a tilapia (#5), produced mucus which reacted with the red cells from all 10 milkfish.

TABLE 2. Reactions of Milkfish Red Cells with Mucus and Sera (Test II)

		Mucus								Sera	
		Snapper				Tilapia				Milkfish,	
Red Cells	*Milkfish*									*snapper,*	*Saline*
Milkfish	*1–10*	*1*	*2*	*3*	*4*	*1–3*	*4*	*5*	*6*	*and tilapia*	*(control)*
1	0	0	0	0	1+	0	3+	4+	0	0	0
2	0	3+	0	3+	3+	0	0	4+	0	0	0
3	0	1+	0	0	0	0	3+	4+	0	0	0
4	0	3+	0	3+	3+	0	3+	4+	0	0	0
5	0	?1+	0	1+	1+	0	3+	4+	0	0	0
6	0	0	0	3+	3+	0	0	4+	0	0	0
7	0	0	0	2+	2+	0	0	4+	0	0	0
8	0	3+	0	3+	3+	0	0	4+	0	0	0
9	0	?1+	0	4+	4+	0	0	4+	0	0	0
10	0	0	0	0	0	0	0	4+	0	0	0

Note: 0, no reaction, cells dispersed; 1+, slight clumping, but most cells dispersed; 2+, slightly larger clumps, interspersed fine strands; 3+, several large clumps, increased number and thickness of strands, loose network, slightly hazy background; 4+, usually one, sometimes a few, large clumps in tight network; well-developed strands in reticular formation; clear background.

Dried preparations of the reactions of mucus with red cells (Figure 1) clearly show details as described in the key. Negative reactions, in addition, show crystalline patterns which are an effect of drying.

DISCUSSION AND CONCLUSIONS

That the reactions of red cells with mucus may have an immunologic basis is suggested by: (i) the variable distribution of individuals among the same species that show reactions and their crossing of taxonomic lines, remindful of blood group systems; and (ii) the known fact, as mentioned in the introduction, that antibodies against mammalian red cells, or immunoglobulins that could have an antibody function against red cells, exist in fish mucus.

The finding of no reaction of red cells with any sera, even from individuals whose mucus was active against red cells, suggests production of the reacting substances locally in the skin rather than being a product from serum. This view is consistent with that of Di Conza and Halliday (1971), who based their view on findings in the catfish, *Tachysurus australis,* of skin lymphoid cells which could be involved in local antibody synthesis, and of differences in hemagglutinins and other immunoglobulins between skin mucus and sera.

My study indicates the basis for a possible immunologic type of incompatibility among certain individual fishes within a given tank population, and further studies are in progress that may elucidate additional aspects of the problem. Specifically, these studies are attempting to determine how widespread are *in vitro* incompatibility reactions of mucus and red cells among and between various species. This effort is being conducted by testing a greater number of individuals of a given species, as well as more species. The studies also are attempting to determine if this type of incompatibility is the cause of *in vivo* debility and eventually disease in certain fishes within the same tank. Evidence is being obtained indirectly by testing debilitated fishes to determine if their red cells are in low number (anemia), and if they will react with mucus of other individuals present. Removal of the latter may then lead to an improvement in the health of the former. A second approach is adding mucus directly to tank

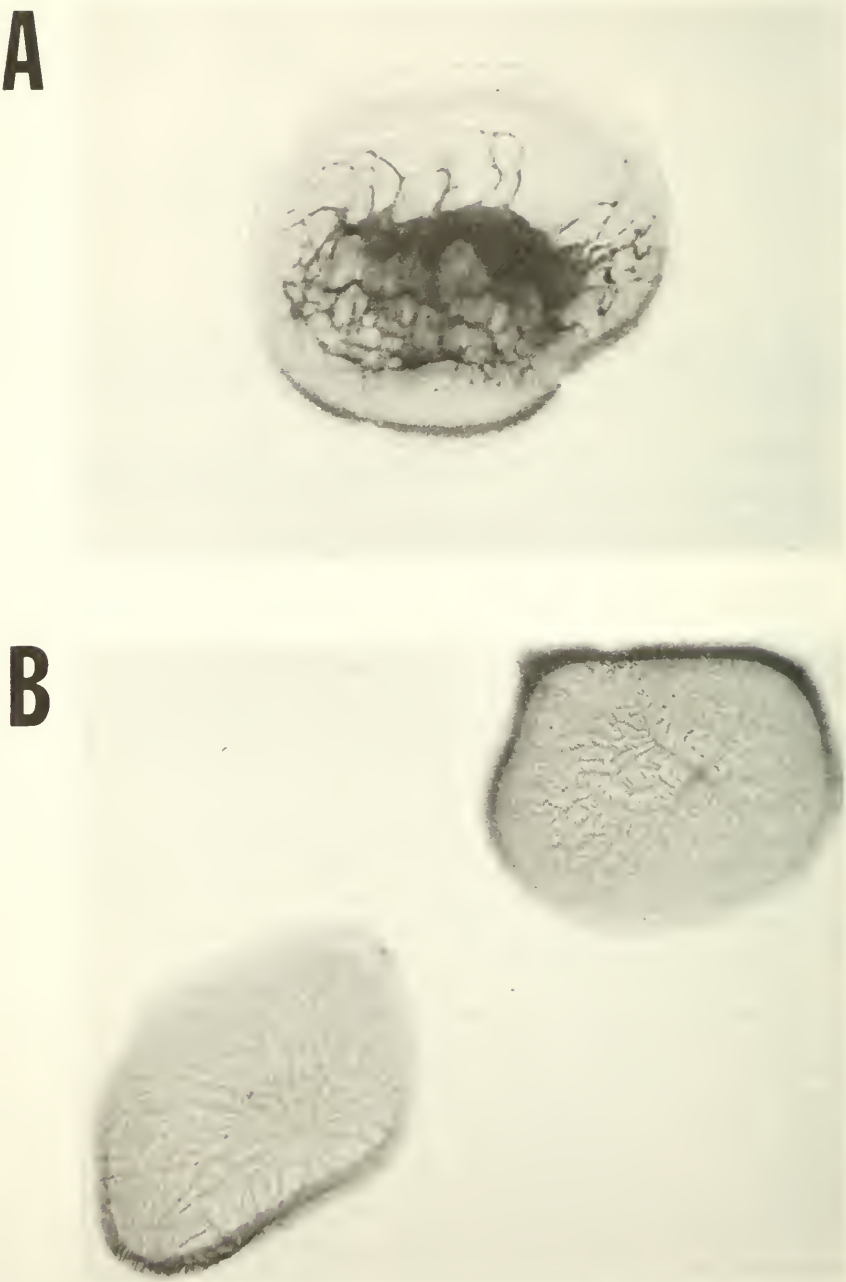

FIGURE 1. Reactions of mucus with red cells. A, 4+ reaction: mucus from snapper #3 with red cells from milkfish #9. B, two negative (0) reactions: mucus from snapper #2 with red cells from milkfish #8 and #9, reading left to right.

populations and watching for signs of failing health in some fishes. These are then bled and their red cells tested for signs of reaction with mucus that had been added. Finally, the studies hope to develop a method to prevent possible debility from reactions of mucus with red cells. One simple method under investigation is rearing fishes through their earliest stages in water which also circulates among adults. This arrangement exposes developing fishes to a variety of foreign substances, including mucus, so that they may be accepted as part of "self" by the maturing immune mechanism. Thus, these substances may not produce reactions, based on sensitization, should later contact be made with them.

ACKNOWLEDGMENTS

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NOTE

Since submission of the manuscript, the following article appeared with information that is consistent with the view of mucus antibodies being produced locally in the skin rather than being derived from serum: Mawdesley-Thomas, L. E. 1975. Some diseases of muscle: 343–363. *In* the pathology of fishes (Edited by Ribelin, W. E., and Migaki, G.). The University of Wisconsin Press, Madison. 1004 p.

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NOTES

EXTENSION OF RED FOX DISTRIBUTION IN CALIFORNIA

The red fox *(Vulpes fulva)* is widespread throughout North America. Hall and Kelson (1959) recognized 12 subspecies of red fox.

In California the Sierra Nevada red fox *(Vulpes fulva necator)* inhabits the high Sierra Nevada and Cascade mountains. It is found chiefly above 2,135 m (7,000 ft) in elevation, seldom venturing below 1,525 m (5,000 ft). The present distribution of the Sierra Nevada red fox extends from near Medicine Lake, Siskiyou County south to possibly Siretta Peak, Tulare County (Schempf and White 1975).

The Central Valley of California has a population of red fox of unknown taxonomic status. This valley population was first noted in the latter part of the 19th century near the Sutter Buttes. Ingles (1965) and Grinnell, Dixon and Linsdale (1937) have suggested that the valley red fox was introduced by man. Its distribution in 1937 included Colusa, Glenn, Tehama, Sutter and Butte counties.

As part of a study concerning carnivores in California the University of California, Berkeley and the California Department of Fish and Game have collected sightings of red fox in California from biologists, game wardens and trappers (Schempf and White 1975).

The valley population of red fox is increasing and extending its distribution north, south and west. Recent observations indicate that the major concentrations of red fox in the Central Valley are found adjacent to the Sacramento River near Red Bluff south to the Butte Sink area, Colusa County.

However, the valley red fox has been observed in Shasta, Trinity, Tehama, Butte, Colusa, Glenn, Sutter, Yuba, Yolo, Napa, Solano, El Dorado and San Joaquin counties (Gray 1975). Isolated observations have been made in Marin and Mendocino counties (Schempf and White 1975) which are near the coast.

ACKNOWLEDGMENTS

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ACORN SELECTION BY BAND-TAILED PIGEONS

In 1975, at the University of California's Hopland Field Station, Mendocino County, California, a heavy crop of blue oak *(Quercus douglasii)* acorns attracted a large population of migratory band-tailed pigeons *(Columbia fasciata)*. In October, 1975, data on feeding behavior of the band-tailed pigeons was collected.

Blue oak woodland is the major plant community in the study area. Average tree density was estimated by Murphy and Crampton (1964) at 494 to 618 trees per ha (200 to 250 trees per acre). Similar findings were reported by White (1966) for oak woodlands in central coastal California. The woodland understory is composed largely of annual grass species (*Avena* sp., *Bromus* sp. and others).

During the hunting season (October 4 through October 19) 29 pigeons were collected and their crop and stomach contents examined. Crop and stomach contents contained only sound acorns of blue oak. Each whole acorn was measured (length and width) and weighed. A random sample of acorns from known pigeon feeding areas was collected and used to characterize and compare the physiognomy of acorns consumed by pigeons and that of all available blue oak acorns. The 't' test for unequal sample sizes (Steel and Torrie 1960) was used to compare the two samples (Tables 1 and 2).

The data from Table 1 indicate that acorns collected from the crops and stomachs of pigeons and those collected at random represented two distinct groups based upon physiognomic characteristics. Furthermore, acorns selected by pigeons were significantly smaller ($p \leq .01$). The greatest differences between samples were observed in width and weight of acorns. When the data were separated into 5 day collection intervals (Table 2) the differences between width and weight remained significant throughout the study period. However, differences in acorn length became progressively less significant.

TABLE 1. Comparisons of Average Sizes of Randomly Collected Blue Oak Acorns and Acorns Collected from Band-tailed Pigeon Crops.

Sample	*Length (cm)*	*Width (cm)*	*Weight (g)*
Crop	2.68	1.29	2.98
Random	2.77	1.72	5.07
't' value	2.98*	19.79*	15.20*

* Significant at the 1% level.

TABLE 2. Average Sizes of Blue Oak Acorns Collected at Five Day Intervals from the Crops of Band-tailed Pigeons.

Date	*No. pigeons*	*No. acorns*	*Length (cm)*	*Width (cm)*	*Weight (g)*
10/4–8/1975	4	16	2.53†	1.31†	2.79†
10/9–13/1975	11	30	2.65*	1.32†	3.06†
10/14–18/1975	14	77	2.73ns	1.27†	2.98†

*, † Differences between average sizes of the random collection (Table 1) and crop acorns collected during each interval are significantly different at the 5% and 1% levels, respectively, using the 't' test for unequal sample sizes.

ns Not significant at the 5% level.

In 1975 average blue oak acorn production per tree on the study area was 2.3 times as heavy as interior live oak *(Q. wislizenii)* and 5.3 times as heavy as black

oak *(Q. kelloggii)*, the second and third most abundant oak species in the area respectively (Fry, unpublished data). This fact may be responsible for the pigeons' exclusive use of blue oak acorns. Smith (1968) stated that band-tailed pigeons usually fed on one abundant food item even though other foods were available. Similar findings were reported by Murton (1971) for the European wood pigeon *(C. palumbus)*.

Gibb (1970) found that the New Zealand pigeon *(Hemiphaga novaeseelandiae)*, feeding on cultured plums, rejected fruits larger than 24 mm in diameter. In the present study the band-tailed pigeon was shown to exhibit size-specific selectivity while feeding on acorns. Selectivity in feeding can be the result of structural or functional limitations (Welty 1964). How this may relate to the feeding strategy of the band-tailed pigeon is not known at this time.

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ALABAMA SPOTTED BASS GROW AT RECORD RATE IN LAKE PERRIS, CALIFORNIA

On April 6, 1973, the California Fish and Game Commission authorized the introduction of Alabama spotted bass *(Micropterus punctulatus henshalli)* as part of California's experimental management program for reservoir fisheries enhancement. A previous introduction of northern spotted bass *(M. p. punctulatus)* from Ohio in 1933 was successful to the extent that established populations developed in the Cosumnes River, El Dorado County, and the Feather River, Sutter County (McKechnie 1966). The genetic purity of these stocks is questionable, however, and it is believed that hybridization with previously established smallmouth bass *(Micropterus dolomieui)* populations may have occurred. Brood stocks of spotted bass were not maintained within California's hatchery system and a reintroduction of the species was, therefore, authorized.

The decision to introduce Alabama spotted bass (as opposed to a reintroduction of the northern form) was based largely on the rapid growth and longevity they achieve in certain oligotrophic impoundments in Alabama (Gilbert 1973). Lewis Smith Lake, Cullman, Walker, and Winston counties, for example, regular-

ly produces spotted bass in excess of 2.3 kg (5 lb) and a number of Age VI, VII, and VIII specimens have been identified (Webb and Reeves 1975). Because of the possibility that genetic factors may be partially responsible for the rapid growth of spotted bass in Lewis Smith Lake (Samuel L. Spencer, Ala. Dept. Cons. and Nat. Res., pers. comm.), it was decided to obtain fish from this source for importation to California.

Personnel from the Alabama Department of Conservation and Natural Resources collected approximately 130 adult spotted bass from Lewis Smith Lake in the winter of 1973–74. These specimens were then flown to Ontario, California by California Department of Fish and Game pilots Carrol Faist and Pat Simon on January 25, 1974. Following inspection for diseases and parasites and the removal of the left ventral fin, 94 individuals ranging from approximately 25 cm (10 inches) to 0.9 kg (2 lb) were released in Lake Perris, Riverside County. Remaining specimens, aside from six individuals which were preserved in formalin, were then transferred to Central Valleys Hatchery (Sacramento County).

Lake Perris, the southern terminal reservoir for the California State Water Project, is an 809-ha (2000-acre) impoundment located about 48 km (30 miles) southeast of San Bernardino. Dam construction was essentially complete in 1973 and initial water storage began in that year. The reservoir has the high basic fertility associated with California impoundments south of the Tehachapi Mountains. At present, Lake Perris contains significant populations of Alabama spotted bass, channel catfish (*Ictalurus punctatus*), green sunfish (*Lepomis cyanellus*), and rainbow trout (*Salmo gairdneri*).

Reproduction of spotted bass in Lake Perris was first confirmed in July 1974, when a number of fingerlings were collected with electrofishing gear. Subsequent observations with SCUBA equipment in the fall of 1974 again revealed the presence of numbers of Age 0 spotted bass which appeared to average about 15 cm (6 inches) in length. Continued sampling through 1975 failed to confirm successful spawning in that year although the presence of a small number of 20 to 23-cm (8 to 9-inch) specimens in early 1976 appeared to indicate that some reproduction had occurred.

Creel checks at Lake Perris in 1974 and 1975 recorded only an occasional spotted bass in the sport catch. On January 3 and 10, 1976, however, angling companions David W. Nollar and Daniel Leader reported an aggregate (or combined) catch of approximately 50 spotted bass over the 2-day period. Fish caught ranged from an estimated 0.7 kg (1.5 lb) to 2.6 kg (5.7 lb). The weight of the largest specimen was later confirmed by the first junior author who judged the fish to be approximately 46 cm (18 inches) in length. Leader, who caught the largest fish on January 3, also took a five-fish limit on January 10 which weighed over 7.7 kg (17 lb).

Scale samples were taken from the largest specimen (which was being mounted by a taxidermist) at a point near the tip of the left pectoral fin for an analysis of age and growth characteristics. The sample was cleaned and mounted on a cellulose acetate strip and examined with the aid of an Eberbach scale projector with a magnification of 42×.

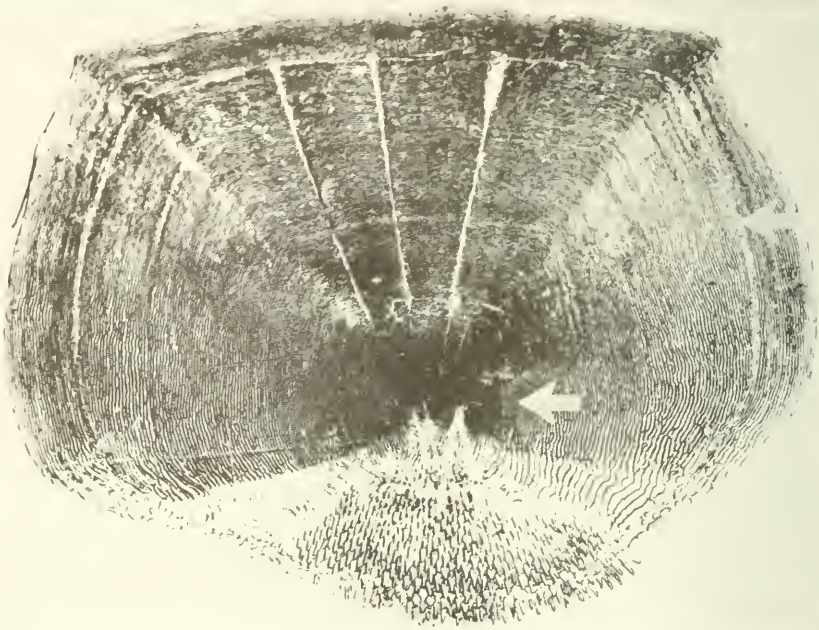

FIGURE 1. Photograph of scale from 2.6 kg Alabama spotted bass taken from Lake Perris on January 3, 1976. Arrows depict annuli. The inner annulus is considered questionable because of the lack of cutting over in the lateral field. Photograph by Jack Kelley Clark, Cooperative Extension, University of California at Davis.

Examination of the scale sample revealed the presence of a single well defined annulus near the margin (Figure 1). There appeared to be some possibility that a centrally located (although poorly defined) annulus was also present. In our judgment, the central annulus (if valid) was laid down in 1975 while the outer annulus represents the 1976 mark. Conversely, if the central mark is not a true annulus, the outer annulus would be presumed to have been laid down in 1975. In either event, we judge this specimen to be a member of the 1974 year class (as opposed to an originally stocked specimen) and this view is supported by the following evidence: (1) the fish was unmarked (all fish originally stocked were marked by removal of the left ventral fin); (2) spotted bass from Lewis Smith Lake form easily recognizable annuli (Webb and Reeves 1975) and examination of representative scale samples from the original stock prior to their introduction most often showed two well defined annuli (Figure 2); and (3) the present abundance of large spotted bass in Lake Perris lends credence to the notion that the 1974 year class grew at an exceptionally rapid rate.

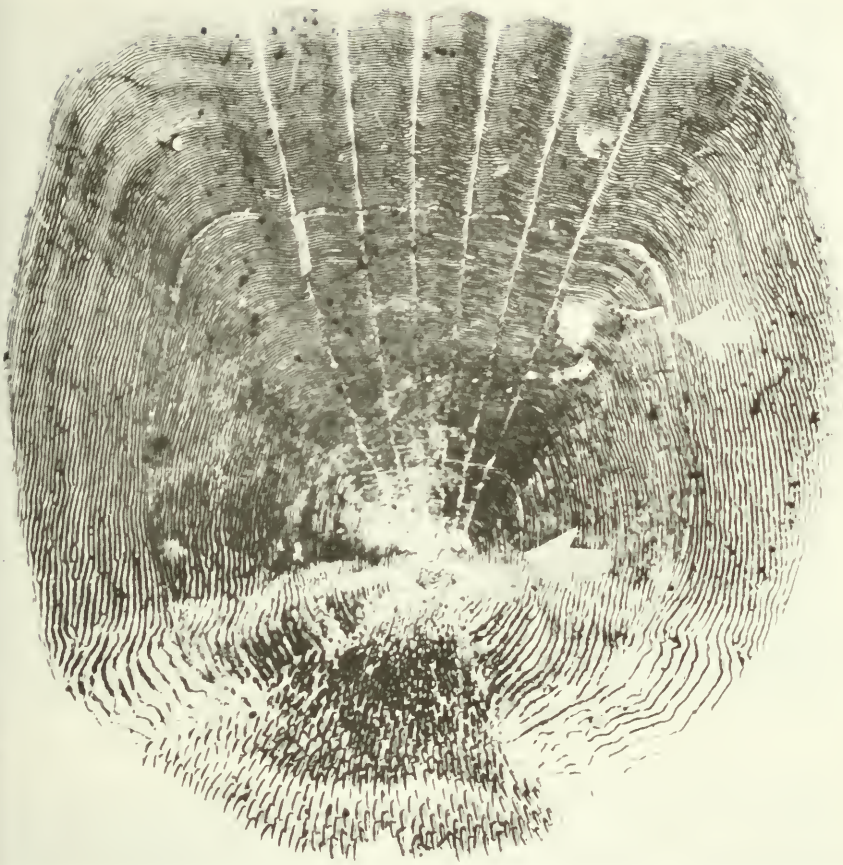

FIGURE 2. Photograph of scale from 30.5 cm Alabama spotted bass taken from Lewis Smith Lake, Alabama, in January 1974. Arrows depict annuli. Scale configuration was representative of specimens originally introduced into Lake Perris. Photograph by Jack Kelley Clark, Cooperative Extension, University of California at Davis.

To the best of our knowledge, the growth achieved by this individual constitutes a record for the species over a 2-year interval. At Lewis Smith Lake, the most rapidly growing specimens do not reach 45.7 cm (18 inches) until near the end of their fourth growing season (Webb and Reeves 1975). The most rapid early growth previously recorded occurred at Granada Reservoir, Mississippi, where spotted bass reached a mean length of 27.9 cm (11 inches) at Age II (Towery 1964).

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BIRTH OF A CALIFORNIA SEA LION, ON SOUTHEAST FARALLON ISLAND

The California sea lion, *Zalophus californianus* (Gill), is distributed along most of the western coast of North America, occurring from British Columbia in the north (Hancock 1970), south to the tip of Baja California and throughout the Gulf of California (King 1964). North of the central California coast, however, the population is thought to be composed entirely of males, and the northernmost breeding colony is located at Point Piedras Blancas, San Luis Obispo County (Lat 35° 40' N) (Peterson 1968). Thus, we consider it to be an event of no small significance that we observed the presence of a pregnant female California sea lion on Southeast Farallon Island (Lat 37° 45' N) in June 1974, and subsequently in July 1974 the presence of a female with a newly born pup was noted.

The initial observations were made at approximately 2000 hours on 12 June 1974, when Raymond J. Pierotti and T. James Lewis observed a small California sea lion being actively pursued by a large adult male of the same species. Subsequent observation through binoculars revealed that the smaller individual was a female with a visibly distended abdomen that dragged across the rocks as she moved. The male appeared to be attempting to sniff the ano-genital region of the female, a pattern generally associated with pre-copulatory behavior in this species (Peterson and Bartholomew 1967).

In late June, David G. Ainley observed a newborn sea lion pup on the island, but because Steller sea lions, *Eumetopias jubatus* (Schreber), breed annually on the Farallones, it was assumed that the pup was a stray of this species. However, on 10 July, Malcolm Coulter and Pierotti were observing the behavior of Western gulls, *Larus occidentalis* (Audubon), from a blind high above the water wher we noticed an unusually small sea lion with a pup on some rocks adjoining the water. It was our opinion that the female sea lion with the pup was a California sea lion, but at the time we were too far away to confirm our initial impression. We proceeded to maneuver more closely to the sea lions, collecting three more witnesses (Lewis, James Higbee, and Roger Stoll) in the process. Eventually, two of us were able to approach to within 10 m (33 ft) of the pair and take a series of photographs (Figures 1 and 2). The female became agitated by our presence and rose up and emitted the characteristic *Zalophus* "bark". Subsequently, the pair was also observed by Ainley and by Robert Boekelheide, another employee of the Point Reyes Bird Observatory.

These observations are of significance not only because the breeding distribution of the California sea lion is extended by about 300 km (180 miles), but it is also the most northerly record of a live female *Zalophus* (Bruce Mate pers. commun.). We are hopeful that this mother and pup may be the advance guard of a future breeding colony of *Zalophus* on the Farallones. Particularly, because it was in a very similar manner that the Northern elephant seal, *Mirounga angustirostris* (Lesson), began its recolonization of the Farallones in 1972 (LeBoeuf, Ainley, and Lewis 1974), and the South Shetland fur seal, *Arctocephalus*

tropicalis gazella (Peters), established itself at Cape Shireff in the South Shetland Islands (O'Gorman 1961).

FIGURE 1. Female *Zalophus californianus* with pup on Southeast Farallon Island, July 10, 1974. Photograph by author.

Even more encouraging is the fact that T. James Lewis reported the birth of a California sea lion pup from Southeast Farallon Island in June of 1975. We do not know if this is the same female observed in 1974, but if so, this indicates that the female not only gave birth on the Farallones, but was impregnated there as well. There is evidence from archaeological digs that California sea lions may have bred on these islands in the last century, but were eliminated by sealers. It is to be hoped that this sad tale is being reversed today through the combined efforts of the Point Reyes Bird Observatory and the U.S. Bureau of Sport Fisheries and Wildlife to maintain the Farallones as a national wildlife refuge.

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OBSERVATIONS ON THE BREEDING BEHAVIOR OF THE HARBOR SEAL, IN HUMBOLDT BAY, CALIFORNIA

INTRODUCTION

The harbor seal of the eastern Pacific, *Phoca vitulina richardi,* frequents estuaries, tidal sandbanks, and offshore rocks from Baja California, Mexico to the northern coast of Alaska (Scheffer 1958). Due to its highly aquatic and secretive habits, little is known of the harbor seal's behavior. Quantitative behavioral studies have relied largely upon the observation of captive animals (Finch 1966; Schusterman 1968). However, aspects of harbor seal behavior in the wild have been described by Biggs (1969), Bishop (1967), Fisher (1952), Newby (1973), Scheffer and Slipp (1944), and Venables and Venables (1955, 1957, and 1959).

This is a report on a 300-hr study of a pupping colony of harbor seals in Humboldt Bay, California (Lat 40° 45′ N, Long 124° 10′ W) during the spring of 1973. The southern part of the bay is a shallow body of water, 4 miles long and 2 miles wide, with deep channels along which seals haul out during each low tide. I made daily observations of these animals between March and June from an observation tower located within the rookery. Binoculars (7X50) and a spotting scope (40X) aided observations which were usually at distances of 20 to 100 m (66 to 330 ft). A blind mother and her 10-day old pup were marked with a lanolin-emulsion sheep marker (Kemp's Branding Liquid, William Cooper and Nephews, Chicago).

OBSERVATIONS

The Pupping Colony

Seasonal movements of seals into South Bay began in the first months of the year. By March 23, 1973, when the first pup appeared, there were 67 seals; by April 26, the number of pups had peaked at 88 and there were 337 seals in the bay.

The scattered herds of the colony were open groups, showing changes in composition, number, and location as they broke up with each high tide and reformed on the ebb.

Although harbor seals show some sexual dimorphism in body size (Biggs 1969), I was able to sex seals only by determining the location of genital openings as the animals rested on land. Usually, herds included males, females, yearlings, and mothers with pups, as was the case in Mugu Lagoon, California (Evans and Bastian 1969). However, beginning on April 19, I repeatedly observed herds in which every seal that could be sexed was an adult male (Table 1).

TABLE 1. Observations of Male Herds in South Humboldt Bay.

Date	*Herd size*	*Males*	*Females*	*Total sexed*
4/27/73	13	6	0	6
5/21/73	13	12	0	12
5/28/73	23	13	0	13
5/30/73	11	7	0	7

Males in these herds often bore scars about the face and neck, and sometimes had erections as they rested on their sides. Such nonrandom associations of sexes suggest the presence of breeding competition between males, leading to the formation of bachelor herds of subordinate males. Alternatively, sexes may tend to segregate until females begin to come into estrus, shortly after pups are weaned (Bishop 1967). To my knowledge, male groups of harbor seals have not been reported.

Parturition

On April 12, 1973, at 1721 hours, I witnessed the birth of a harbor seal pup. The female was alone and moved restlessly across the mud flats for about 30 min before the brief delivery. Presentation was cephalic. By the time the pup struck the mud, the umbilical cord had broken and the amniotic sac had burst. Simultaneously, two Western gulls, *Larus occidentalis,* landed nearby but did not interact with the mother and the newborn pup. The pup was born in juvenile pelage.

For 80 min following birth, I recorded the activities of the mother and pup (Table 2). During this time I saw no sign of afterbirth and no suckling took place.

TABLE 2. Time Sequence of Postnatal Activities of a Harbor Seal Mother and Pup Following a Birth on April 12, 1973.

Time	*Mother*	*Pup*
0 (Birth)	Lying on belly after 30 min of labor.	Emerges head-first.
20 sec	Approaches and noses pup.	Begins to locomote across mud using foreflippers

4 min	Waves foreflipper at pup and continues nosing	Moving and resting on mud
7 min	Rolls on side in nursing position.	Sniffs mother's abdomen but does not suckle.
10 min	Follows pup through shallow water.	Splashes through shallow water at edge of channel.
13 min	Rolls on side in nursing position.	No suckling.
20 min	Rolls on side in nursing position.	No suckling; swims into deep water.
30 min	Swimming after pup and nosing pup after dives.	Swimming and diving near mother.
40 min	First mutual nosing in water.	Dives for 30 sec.
55 min	Carries pup briefly on her back for first time.	Rides piggyback, then swims from mother.
70 min	Carries pup briefly on her back.	Rides piggyback, then swims from mother.
80 min	Observation ends at dusk.	

The newborn pup displayed extremely precocial behavior. It moved actively on the mud within the first minute after birth. It entered shallow water at 10 min post partum. It swam independently in deep water from 20 min post partum until the observation ended at dusk.

Postnatal interactions between mother and pup involved frequent nose-nose contact on land (e.g. nosing for 45 sec of a 1-min observation at 4 min post partum) and in water. The mother did not lick or groom her pup. All perinatal activity took place in the absence of other seals.

Births of harbor seals have been reported by Bishop (1967) and Klinkhart (1967). All births recorded for *P. v. richardi* appear to have been cephalic presentations and terrestrial.

FIGURE 1. A harbor seal mother nurses her 6-day old pup on the mud flats of Humboldt Bay. Photograph by the Author (1973).

Mother-pup Bond

Observations of the marked mother and pup suggest a maternal bond that is highly specific. The two seals were always seen together until weaning. Only once did a strange pup attempt to suckle the mother; the mother rebuffed the attempt with foreflipper waves and bites.

The maternal bond was apparently maintained by the pup's unilateral vocalizations, as well as by visual and olfactory cues. Mothers and pups were together continuously and were not bound to specific herds.

Mothers with pups did not regurgitate after hauling out on the ebb as did many other seals; and because some mothers became noticeably emaciated through the lactation period, it appears that mothers may have fasted or fed only sparingly during the continuous mother-pup nursing bond.

All observed nursing occurred on land or in a few inches of water (Figure 1), although aquatic nursing has been reported in harbor seals (Finch 1966; Venables and Venables 1955). Nursing periods were usually spaced several hours apart during low tide haul-out. The mean length of a nursing period was 6.6 min (S.D.=3.4) for 23 observations.

Pups initiated these periods by nosing their mothers' abdomens and terminated them by simply ceasing to suckle. Mothers initiated nursing periods by rolling on their sides to expose abdominal teats and terminated them by rolling back on their bellies. Mothers sometimes used foreflipper waves, a familiar harbor seal threat, to regulate the duration of suckling by pups.

The marked pup was weaned at between 5 and 6 weeks of age.

Pup Ontogeny

Suckling pups could be roughly aged on the basis of changes in body size, manner of locomation on land, and condition of the umbilical cord remnant (Knudtson 1974). The marked pup lost the 8- to 10-cm (3- to 4-inch) cord remnant at between 8 and 10 days of age.

Pups as young as 6 days old displayed a crude version of the adult foreflipper wave. Pups rode piggyback on their mothers' backs in the water as early as 55 min post partum. Some pups were slapping the water with their foreflippers when disturbed, in the manner of adult harbor seals, by the 3rd week following birth. Suckling pups dove for as long as 2 min.

Copulation

Throughout the study period I repeatedly observed stereotyped aquatic interactions between unsexed pairs of seals. Twice they included dog-like mounts by one of the pair. These encounters were characterized by deliberate foreflipper and hindflipper slaps, nuzzling and biting, and synchronous rolling dives. They resembled descriptions of courtship in *P. v. vitulina* by Venables and Venables (1957), although Bishop (1967) suggests that such rolling encounters are probably incipient sexual behavior or play rather than actual breeding interactions.

CONCLUSIONS

Although data is still lacking for an adequate description of the harbor seal breeding system, its principal features appear to include: an open herd structure with a distinct absence of territorial or harem maintaining activity; possible male-exclusion pressures, as evidenced by herds of males; an aquatic copulation

(Bishop 1967; Venables and Venables 1957); a continuous mother-pup nursing bond that is uninterrupted by copulation or abandonment until weaning; a terrestrial nursing-suckling relationship; a maternal aggressiveness towards other adults (Knudtson 1974); and an estrus that occurs shortly after weaning (Bishop 1967).

Such features could best be encompassed within a promiscuous breeding plan in which adult males compete for cows entering the post-weaning estrus. In such a system, competition between rival males could lead to bachelor herds of subordinate males and mothers would become receptive to the advances of dominant males only after pups were weaned. Males would than consort with females approaching estrus, forming transient tending-bonds culminating in copulation. Because females would no longer be bound to land-based nursing duties, copulation would usually be aquatic. Opportunistic breeding by males would lead to greater reproductive success than would territoriality in this competition for mobile aquatic females.

Other studies have suggested both promiscuity (Scheffer and Slipp 1944) and monogamy (Evans and Bastian 1969) as the basis for a harbor seal breeding system. Long term studies of harbor seal breeding strategy using tagged seals remain to be carried out.

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Peter M. Knudtson, Star Route, Trinidad, California 95570. Accepted November, 1975.

NOTES ON SOME FISHES COLLECTED OFF THE OUTER COAST OF BAJA CALIFORNIA

The four fishes listed in this report represent geographic range extensions and definite collection localities. The fishes were collected by the author in otter trawls aboard the Department of Fish and Game research vessel N.B. SCOFIELD and by Los Angeles County Museum personnel, in otter trawls, aboard the research vessel SEARCHER. Latitudes and longitudes have been included for all collecting localities (Table 1). Miles are in nautical miles.

TABLE 1. Latitudes and Longitudes of Localities of Capture (Arranged from North to South)

Locality	*Latitude*	*Longitude*
Baja California		
Ballenas Bay (12.6 km SE of Abreojos Point)	26°36.4'N.	113°33.2'W.
Ballenas Bay (20.4 km SE of Abreojos Point)	26°31.3'N.	113°35.1'W.
San Juanico Bay (5.6 km SE of Pt. Pequena)	26°12.8'N.	112°25.8'W.
Magdalena Bay (4.6 km S of Pt. Redonda)	24°28.5'N.	112°02.5'W.
Tosca Point (37.0 km SE)	24°12.0'N.	111°22.0'W.
Tosca Point (64.8 km SE)	24°07.0'N.	111°05.0'W.
Marquez Point (9.2 km W)	23°57.0'N.	110°58.0'W.
Marquez Point (37.0 km SE)	23°38.0'N.	110°43.0'W.

Raja inornata (Jordan and Gilbert)—California skate

One California skate was captured 13 km (6.8 miles) SE of Abreojos Point on March 13, 1975, in 57 m (31 fm) of water. The total length of the skate was 480 mm (18.9 inches) and the wing length was 319 mm (12.6 inches). My identification was confirmed by Carl L. Hubbs, Scripps Institution of Oceanography, La Jolla, California. This specimen is now in the ichthyological collection at Scripps Institution of Oceanography (SIO 75–379).

This fish extends the known range southward approximately 176 km (95 miles) from Turtle Bay (Miller and Lea 1972) to Ballenas Bay.

Zaniolepis latipinnis Girard—longspine combfish

On March 13, 1975, a longspine combfish was captured 20.4 km (11.0 miles) SE of Abreojos Point in 91 m (50 fm) of water. The total length of the specimen was 143 mm (5.63 inches) and the standard length was 124 mm (4.88 inches).

The occurrence of the longspine combfish off Abreojos Point extends the range south from San Cristobal Bay, as recorded by Knaggs, Sunada and Lea (1974), to Abreojos Point, a distance of 140 km (77 miles).

Oxyjulis californica (Gunther)—senorita

Seven senorita were captured 5.6 km (3.5 miles) SE of Point Pequena on March 11, 1975, in 22.0 m (12 fm) of water. The specimens were inadvertently thrown overboard before any measurements could be taken.

The previous southern limit of their range was Cedros Island (Miller and Lea 1972). The capture of these fish off Point Pequena extends their southern range 366 km (198 miles).

Prionotus gymnostethus (Gilbert)—searobin

On March 10, 1975, two specimens were captured by Department of Fish and Game personnel 4.6 km (2.5 miles) S of Point Redonda in 80 m (44 fm) of water. The specimens were identified by John Fitch (CF&G). They measured 100 and 101 mm (3.94 and 3.97 inches) standard length (SL) and are now deposited in the collection of the Natural History Museum of Los Angeles County (LACM 34355-1).

While looking for other individuals of this species it was learned (J. Fitch, pers. commun.) that the Los Angeles County Museum of Natural History had specimens collected from the outer coast of Baja California on which no range extensions had been published. Therefore, I have included their collections of this species with ours.

The following specimens were all captured with a 4.9-m (16-ft.) otter trawl on February 1, 1971, in different localities, by Los Angeles County Museum personnel aboard the research vessel SEARCHER. These specimens are located in the ichthyological collection at the Los Angeles County Museum. Two specimens (LACM 31770-4) measuring 79 and 92 mm (3.1 and 3.6 inches) SL were captured 37 km (20 miles) SE of Point Tosca in 84 m (46 fm) of water. Two smaller specimens (LACM 31771-10) of 18 and 26 mm (0.7 and 1.0 inches) SL were taken 65 km (35 miles) SE of Point Tosca in 26 m (14 fm) of water. Two more specimens (LACM 31772-4) of 91 and 110 mm (3.6 and 4.3 inches) SL were captured 9 km (5 miles) W of Point Marquez in 76 m (42 fm) of water. Six specimens (LACM 31773-7) ranging in size from 72 to 105 mm (2.8 to 4.1 inches) were taken 37 km (20 miles) SE of Point Marquez in 110 m (60 fm) of water.

Walker and Norris (1952) report the northern limit of this species range as being the Gulf of California. This is the first time this species has ever been reported from the outer coast of Baja California and represents an extension of 276 km (150 miles) northward from the southernmost tip of Baja.

ACKNOWLEDGMENTS

I wish to gratefully acknowledge the assistance of Ralph Rodrigues, Milan Marott, and the rest of the crew on the N.B. SCOFIELD. I especially want to express may thanks to John Fitch for his assistance in identifying specimens and for his suggestions concerning the manuscript. I would also like to thank Robert J. Lavenburg, Curator of Fishes at the Los Angeles County Museum of Natural History, for allowing me to publish information concerning specimens collected by the museum and for his suggestions concerning the manuscript.

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Glenn F. Black, Operations Research Branch, California Department of Fish and Game, 350 Golden Shore, Long Beach, Calif. 90802. *Accepted March 1976.*

BOOK REVIEWS

Mammals of the World

By E. P. Walker, F. Warnick, S. E. Hamlet, K. I. Lange, M. A. Davis, H. E. Uible, and P. F. Wright. The Johns Hopkins University Press, Baltimore, 1975. 1:xlviii + 1-644; 2:viii + 647-1500; illustrated. Third edition, revised by John L. Paradiso. $37.50.

The third edition of *Mammals of the World* will remain a useful reference tool, just as the first and second editions were. The first edition (1964) went through two printings; the second edition was published in 1968. The current edition is similar in format to the previous two, but because of the impracticality of updating Volume III, a classified bibliography of world-wide mammalian literature, it has been eliminated. The bibliography at the end of Volume I remains unchanged. Where new references appear, citations have been incorporated into the text.

Mammals of the World includes accounts of 1,050 genera, as well as brief ordinal and familial descriptions. Approximately 2,000 figures illustrate the volumes, of which about 270 are new. In addition to providing a photograph of nearly every extant genus of mammal, closeups and line-drawings of various anatomical features are included. The text which accompanies each generic account provides general information on physical characteristics and natural history. Unfortunately, the text does not provide adequate comparative information which would readily allow the reader to distinguish between genera.

Mammals of the World will continue to warrant a place on the bookshelves of interested laymen, and in the libraries of wildlife biologists. Amateur naturalists will find it fascinating reading, and it will remain a valuable reference source for professional scientists. Because of the quality of the volumes, and the amount of material included, this work is a bargain at the asking price.—*Vernon C. Bleich*

SHAD FISHING

By C. Boyd Pfeiffer; Crown Publishers, Inc., 1975, 177 p., illustrated, $8.95.

The popularity of sport fishing for shad is growing extremely rapidly on both coasts, and the need for a complete book on shad angling is strongly felt by novices and experts alike. C. Boyd Pfeiffer has filled this need by producing a classic which is bound to become the bible for shad anglers.

He discusses the history of shad fishing, summarizes the biology and life history, and devotes most of the book to the proper tackle, equipment, flys and lures, and techniques for catching shad. Although the emphasis of his book is on the Eastern Seaboard, it also covers fishing on the West Coast, and the techniques and tackle described are applicable on both coasts. A large list of fly patterns is included in his treatise with instructions for tying them.

After he has guided you to the best locations, taught you the techniques of catching shad, and equipped you properly, he then proceeds to give you lessons in preparing shad for gourmet recipes, which are also included in this complete guide. It is in this section where I have a minor, and perhaps trivial, disagreement with the C. Boyd Pfeiffer. He presents what he refers to as two methods of boning shad. The first, which he indicates is much simpler, is presented with photographs. Although he describes this method very simply, he may not cover it in sufficient detail to enable a novice to bone shad. Also, his "simpler method" does not remove the row of bones along the center of the fillet.

The alternate method (that described by the California Department of Fish and Game) is given by Pfeiffer without photographs and labeled "more complex". Aside from the removal of the lateral strip of bones by what he refers to as the "more complex method", there is really very little difference in the two techniques. However, the method discussed by CF&G describes the similar process in much greater detail and was originally given with many photographs. His gourmet recipes appear to be excellent, and I can't wait to try some of them.

This book should prove invaluable to anyone wanting to learn about shad fishing and will be a valuable addition to the bookshelf of the veteran shad angler.—*John Radovich*

The Fishes of Missouri

By William L. Pflieger; Missouri Dept. Cons., 1975; viii + 343 p. profusely illustrated; soft cover $7.50, hard cover $10.00.

Written by a professional biologist, *The Fishes of Missouri* is a very comprehensive volume which will provide a wealth of information for Missouri sportsmen and biologists alike. The illustrated keys to the 26 families of fishes found in Missouri quickly lead the reader to the correct generic/specific key. At the start of each chapter is a brief discussion of a particular family of fishes, then the illustrated generic/specific key which directs the reader to a page for detailed information on an individual species. The information for a species includes the common and scientific names, a description,

distribution maps, and a discussion of distribution, habitat, habits, life history, and the species' importance to man. Fifteen pages of colored, underwater photographs, a glossary, and reference section, combined with excellent drawings in the keys by Lynne Taylor, make this an excellent, easy-to-use book.—*K. A. Hashagen, Jr.*

The Soft-Hackled Fly

By Sylvester Nemes; Chatham Press, Old Greenwich, Conn., 1975; 130 p. color plates and black and white photographs; soft cover $3.95, hard cover $7.95.

Not a new type of fly and no special equipment or innovative techniques are required to catch fish on it—the soft-hackled fly. Mr. Nemes discusses the history of this sparsely dressed, wingless wet fly; provides a detailed photographic sequence illustrating the tying of a number of his more successful patterns; and relates how, when, and where to fish his patterns. Nothing new, but a method of fishing that has fallen into disuse (and to some extent, disrepute) with the advent of the no hackles, emergers, skittering caddis, etc. Mr. Nemes fishes with no other flies and catches fish where others fail using the "traditional" techniques; I intend to tie up a few and give 'em a try—who knows!—*K. A. Hashagen, Jr.*

The Practical Fly Fisherman

By A. J. McClane; Prentice Hall, N.J., 1975; x + 271 p. 4 color plates; $10.00.

If I were asked to recommend a single book for a beginning fly fisherman, *The Practical Fly Fisherman* would definitely be the book. There are two main reasons I would pick this book over the many fly fishing books available. First, Al McClane is the expert's expert on matters of fly fishing. McClane first wrote this book in 1953 and updated it for this 1975 reissue; it required very little updating. His philosophies have stood the test of time, his predictions have become fact, and his techniques have remained unchanged. Second, McClane can write. He knows his subject and he knows words. I enjoy reading his publications both for the knowledge and the style of writing.

The initial four chapters are about equipment and its use—rods, lines, leaders, and reels, and a detailed, but easy-to-read chapter on casting. Five chapters discuss the various types of flies and how to fish them. Fly fishing for bass and panfish are the subject of two additional chapters. Each chapter has been updated at the end, which allows the reader to be aware of the time differential between editions. The price has increased from $5.95 to $10.00, but it is well worth the increased price.—*K. A. Hashagen, Jr.*

Culture of Marine Invertebrate Animals

Edited by W. L. Smith and M. H. Chanley; Plenum Press, New York and London, 1975; 337 pp., illustrated.

This book is based on presentations at the conference on Culture of Marine Invertebrate Animals held in Greensport, New York in October, 1972. A total of 20 papers by 36 contributors are inclusive. Contributors include a number of recognized authorities of marine invertebrate culture. Although the subject matter is broad, the book is conveniently divided into two parts.

Part I, consisting of seven papers, delves into the supportive aspects of marine culture. Topics include recirculating system culture methods, maintenance of marine filter feeders, phyto-plankton culture, pathogens associated with cultured bivalve mollusk larvae, marine microbiology relative to aquaculture and the use of antibiotics in the culture of marine invertebrates. The latter subject matter, the paper on phytoplankton culture, and the presentations on bacterial pathogens, and marine microbiology are outstanding, and will be most-welcomed by those engaged in aquaculture investigations.

Part II is comprised of specific culture techniques for a wide selection of invertebrates representing several phyla. Beginning with the coelenterates and proceeding to the bryozoa, polychaetes, crustacea, echinoderms and mollusks, general culture procedures are outlined. In certain instances the culture methods presented for a group are essentially a review (e.g. coelenterates); while methodology discussed for crustacean and molluscan forms represent more recent advances in culture practices.

Whether one is engaged in University level research, in a relatively small-scale experimental set-up, or a large-scale shell-fish production operation, they will find this book valuable. It represents one of the most useful recent contributions to the literature of marine invertebrate culture.—*Earl E. Ebert*

The Ageing of Fish: Proceedings of an International Symposium

Edited by T. B. Bagenal, Unwin Bros. Ltd., The Gresham Press, Old Woking, Surrey, England, 1974; vi + 234 p., illustrated. £5. paper.

Since this symposium was sponsored by The European Inland Fisheries Advisory Commission of F.A.O., The Fisheries Society of the British Isles, and The Freshwater Biological Association, it follows that the underlying theme concerns freshwater fishes and fisheries. Twenty-one papers by 22 authors are grouped under five major categories: Some considerations of the scientific basis of age determination (6 papers); Mechanical aids to age determination (2 papers); Elimination of errors in age determination (6 papers); Some sources of age reading errors (2 papers); and The effects of errors in age determination on subsequent studies (5 papers).

Although some authors had more new information to report than others, and some obviously had not done their homework as well as they could have, all of the contributions are pertinent and meaningful. I was especially interested in the information offered in a 12-page report by K. Simkiss entitled "Calcium metabolism of fish in relation to ageing," and believe that salmonid biologists (particularly) would do themselves a favor by taking note of his statement that "there is no evidence for any resorption of otoliths . . ."

Giorgio Pannella offers a great deal of sound advice in his contribution entitled "Otolith growth patterns: an aid in age determination in temperate and tropical fishes." He explores briefly such phenomena as daily, bimonthly, monthly, and annual growth, and illustrates these patterns with some excellent scanning electron micrographs. In light of his comment that "because the daily journal can be followed in otoliths and not in scales, the precision and amount of data are far superior in the former," fishery biologists who, historically, have depended upon scale readings might find it enlightening to investigate otoliths.

One of the weakest (poorest) of the 21 contributions, in my opinion, is a nine-page report by C. P. Mathews entitled "An account of some methods of overcoming errors in ageing tropical and subtropical fish populations when the hard tissue growth markings are unreliable and the data sparse." Confusion as to species involved, questionable ageing techniques, sloppy proofreading, and other inconsistencies cast serious doubt on the reliability of the information presented.

Generally, however, these are "quality" reports and so much useful information is presented that this volume should be required as either background or refresher reading for those likely to be involved in age studies or already involved.—*John E. Fitch.*

Marine Game Fishes of the Pacific Coast from Alaska to the Equator.

By Lionel A. Walford; Reprint of 1937 edition published by Univ. Calif. Press; with new 19-page introduction; Smithsonian Institution Press, Washington, D.C. 1974. $15.

Although first published in a limited edition in 1937, out-of-print shortly thereafter, and a collector's item during the past three decades, Walford's *Marine Game Fishes of the Pacific Coast* is still the most helpful publication there is for identifying many of the fishes inhabiting tropical and subtropical waters between Panama and California. Now, with re-publication, not only is it available at a price most of us can afford, it is more useful than ever because of a 9-page "addendum" that updates scientific names, notes changes in common names, lists new species and synonymizes others.

As pointed out by the publisher "This edition is reprinted from the original without change except for the addition of a new introduction . . . and color plates printed on both sides of each page."

Upon comparing this reprint with an original, one can see immediately that the color plates lost nothing in reproduction, but the black-and-white plates now have a dirty grey background.

Although the new information presented in the "addendum" is for the most part priceless, there are omissions, and some groups have been given better coverage than others. Although printing errors are scarce, several very minor items could stand correcting. On p. 13, the range for *Nematistius* should read San Clemente (city), California to Peru, and on p. 18, *Epinephelus niphobles* is misspelled. On p. 14, *Seriola mazatlana* is noted as being of doubtful validity with the suggestion that it may be synonymous with *S. peruana*. My studies of *Seriola* lead me to believe that *S. mazatlana* is a junior synonym of *S. dorsalis*. A dwarf species inhabiting nearshore waters off Central America remains unnamed, but represents a fourth *Seriola* for the eastern Pacific.

What is needed now is a publication covering all the fishes and fish families inhabiting the highly productive stretch of ocean between California and Panama.—*John E. Fitch.*

Fishes in Kansas

By Frank B. Cross and Joseph T. Collins. University of Kansas, Lawrence, Kansas. 1975. 189 pp. $6.00, paperback.

This is the second book on fishes of Kansas published by the University of Kansas Museum of Natural History. The first book, *Handbook of Fishes of Kansas,* was printed in 1967. It was authored solely by Frank B. Cross. The second book is intended as a supplement and a companion to the first book. It is less technical than the first book; for example, there are no keys to species; and it includes more up-to-date information on the status of each species. The new book is written exclusively in lay terms, which makes it useful for those who lack technical training. I like the introductory chapters. They orient the reader to environmental factors that affect fish distribution, the major types of streams and their fish communities, and man's effect on fishes in Kansas.

The chapter on man's effect on fishes describes impacts on fish habitat and on diversity of species resulting from intensive agricultural practices. Agricultural practices have been "cleaned up" in recent years, and deterioration of many streams has been slowed or even reversed. However, irreversible changes in diversity of species have occurred from construction of numerous impoundments throughout the state. Several new species, such as walleye, yellow perch, white bass and northern pike, have been introduced in Kansas lakes and reservoirs, and they have had an impact on native fishes.

A key to families of fishes precedes the bulk of the text, which is devoted to accounts of individual species. Each species account includes: (1) an artist's rendering of the fish, (2) descriptive characteristics of the species, (3) a map showing distribution of the species within the state, (4) information on reproduction and food preference, and (5) a remarks section which serves as a "catch-all" space provides additional information such as best fishing methods, status of the fish, importance of the fish, and, occasionally, methods for cooking the fish.—*Larry Puckett*

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